DOT/FAA/RD-94/10

General Aviation and Vertical Flight
Program Office
Washington, DC 20591

VERTIPORT CHARACTERISTICS

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Final Report

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of Transportation

Federal Aviation
Administration

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**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

FEB 1 1996

Dear Colleague:

Enclosed is a copy of FAA report **FAA/RD-94/10, Vertiport Characteristics**. This document discusses the general physical requirement of vertiports that will be used for commercial passenger service. It compares the current design requirements with what will be required to accommodate large numbers of passengers. It also discusses the experience gained in airport design and the contribution this experience can make to future vertiport design.

The subjects of vertiports and tiltrotor are currently in rapid transition. Several efforts are bringing about significant changes in thinking. The first of these involves the work of the Civil Tiltrotor Development Advisory Committee and their report to Congress now being published and distributed. The second of these involves the work of industry as they consider the design and development of civil tiltrotor (CTR) in several different sizes. The third of these involves the work of the FAA in the development of rotorcraft instrument procedures using the global positioning system.

In 1987, the FAA took aggressive action to start preparing for the implementation of CTR operations. Looking back to the thinking of that time; concepts of CTR design, vertiport design, and CTR operation now look naive and simplistic. Tremendous evolution has already taken place in this thinking and much more is currently in process. CTR promises significant national benefits in terms of aviation capacity and/or decreases in congestion and delay. Much design and planning remains to be done to bring this about. This report will contribute to that process.

Peter V. Hwoschinsky
Acting Manager, Vertical Flight Program Office

Technical Report Documentation Page

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16. Abstract

It is expected that large helicopters (such as the Westland Helicopters EH-101 and the Sikorsky S-92) and the civil tiltrotor (CTR) will become viable, important vehicles for the relief of both ground and airport congestion. As a consequence, the expanded use of vertical flight vehicles will result in scheduled passenger service. To prepare for this eventuality, the characteristics of large heliports and vertiports must be more precisely defined in terms of what will be required to best serve the passenger market.

This report discusses the general physical requirements of large heliports and vertiport used for passenger service. It discusses the current design requirements and compares these to what would be required to accommodate large numbers of passengers. It discusses the experience gained in airport design and the contribution this experience can make to future vertiport design.

Actual designs of vertiports are developed for five urban sites. The facility types and sites are: City Center, Ground Level - Union Terminal, Cincinnati, Ohio; City Center, Elevated - Greyhound Parking Garage, Phoenix, Arizona; Metro Station, Union Station, Washington, D.C.; Suburban - New Site, Mansfield, Texas; On-Airport - JFK International Airport, New York, New York. The report discusses problems encountered in developing these designs and presents the challenge of providing vertiports for urban passengers. The report also provided general costs for developing a vertiport at each location.

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1.0 INTRODUCTION

As a result of recent changes in aircraft design and application, the relationship of a rotorcraft's physical and performance characteristics to facility design criteria are continually being evaluated. This evaluation is taking place both within government by the Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA), and outside of government by industry representatives, particularly rotorcraft manufacturers and trade associations.

For example, this research analysis is being undertaken because vertiport design criteria, as characterized by the FAA and industry representatives, is in a state of transition. One fundamental reason is the recent development of larger more technologically advanced rotorcraft such as the EH-101, the proposed Sikorsky S-92, the Bell-Boeing civil tiltrotor (CTR) and the European CTR, the European Future Advanced Rotorcraft (EUROFAR). These advanced vertical flight aircraft are being marketed specifically for high density scheduled service. Manufacturers, planners, and government agencies envision these aircraft, the CTR in particular, as one possible solution to both ground and airport congestion. Consequently, significant operational requirements will be imposed by these aircraft on the facilities from which they operate. This evolution in vertical lift transportation will require landing facilities that fully support advanced aircraft operational requirements as well as passenger-oriented services. As a result, certain vertiport design elements need to be enhanced or modified to ensure that specific operational conditions area addressed.

The objectives of this analysis are to: 1) identify the operational requirements of technologically advanced aircraft, and 2) determine how effective existing FAA design criteria are in meeting those requirements. To accomplish this, this study is divided into two parts. The first part is analyzes heliport and vertiport design criteria and aircraft operating characteristics. The study compares the existing criteria presented in FAA's advisory circulars (AC), "Heliport Design," AC 150/5390-2A (reference 1), and "Vertiport Design," AC 150/5390-3 (reference 2), to aircraft operating characteristics, particularly defined by other FAA sponsored projects. In addition, characteristics relevant to airport design issues, as well as military heliports, were also examined in relation to heliports and vertiports.

This analysis examines how design characteristics for vertiports that support large-scale passenger transportation are developed. Consequently, factors such as operational capacity (peak hour and annual) and AVF aircraft physical characteristics (e.g., overall dimensions, gross weight, takeoff and landing performance, one engine inoperative (OEI) procedures, and wake vortices/aircraft separation) are assessed in more depth regarding their impact on vertiport design criteria than has previously been considered in FAA vertical flight design ACs.

The second part of this report determines the feasibility and limitations of meeting optimum facility requirements by developing conceptual layouts of vertiports based on the results of the analysis in the first part. It then applies the conceptual layout plans at five existing

locations. The layouts serve as examples of the application of the study's results using current criteria.

It should be noted that several of these sites would be very poor choices for public-use vertiport facilities. Generally this is because the land available is simply too small for public-use facilities (although these sites might be adequate for private-use facilities). These specific sites were chosen several years ago in a time period when the rotorcraft community was focusing on the possibility of 4 to 5 acre vertiports in downtown, urban, "obstacle rich" environments. Since that time, much has occurred to change this line of thinking. Both environmental and capacity issues point to a requirement for significantly larger facilities. Consequently, several of these sites collectively illustrate the types of difficulties and limitations that would be encountered at inadequate landing sites. However, since failure is often more instructive than success, even the poor sites have been included for educational purposes.

At the time, these sites were selected because; 1) they represent a cross-section of urban and suburban locations; 2) each is a unique design challenge; 3) some of the sites had been considered as potential locations for public-use heliports and vertiports in previous studies, and 4) a database of relevant information was available. The conceptual layouts are <u>not</u> based on any plans to actually develop those sites as heliports or vertiports, nor do they signify any intent or commitment by local, state, or Federal agencies to develop landing facilities as shown in this report. The five locations shown in table 1.

TABLE 1 VERTIPORT LOCATIONS

TYPE	LOCATION
City-Center	
Ground level	Cincinnati, Ohio
Rooftop	Phoenix, Arizona
Metro Station	Washington, D.C.
Suburban	Mansfield, Texas
On Airport	John F. Kennedy (JFK) International Airport

When developing facility design criteria to meet a prescribed level of safety, the FAA has, as a policy, drawn a distinction between those facilities that are privately owned and operated and those that are open for public-use, particularly those used for commercial purposes. The FAA typically applies the highest standards at public-use facilities to provide a higher degree of safety for commercial passenger service. This policy is also consistent, for example, with airports that accommodate scheduled service by certificated airlines and therefore must operate under Title 14 Code of Federal Regulations Part 139 (14 CFR 139), as well as airlines which operate under much stricter operating requirements (14 CFR 135 and 121) than do private operators (14 CFR 91).

This report focuses on vertiports that are designed primarily to accommodate scheduled service by all sizes of rotorcraft. However, the design aircraft, the largest aircraft expected to use the facility, is the conceptual Bell-Boeing CTR-22C (see section 1.1.1). These facilities would fall within the FAA's classification of transport heliport and commercial service vertiports. In addition, they are assumed to be public-use, which means that access is available to all users without prior permission. Consequently, this research does not apply to private-use, utility, government, or hospital helipads, heliports, or vertiports.

It should be noted that the Civil Tiltrotor Development Advisory Committee (CTRDAC) has used the 40-passenger CTR-2000 as their design aircraft. This was based on the CTRDAC's conclusion that the CTR-22C would NOT be an appropriate aircraft for introduction into civil use (reference 3). However, the analysis documented in this technical report was well underway when the CTR-2000 design concepts were first advanced. Funding was not available to update this report to be consistent with the CTR-2000 design concept. On a much broader scale, funding was not available to update this report to be consistent with all of the findings of the CTRDAC report. The CTRDAC findings and recommendations can be expected to have an impact on vertiport design requirements. Interested parties would be well advised to read reference 3 with care in order to gain an early understanding of what changes can be anticipated.

1.1 CERTIFICATION AND DESIGN ISSUES

1.1.1 Certification and Design

The FAA's aircraft certification process and operating limitations, as stipulated in the appropriate Federal Aviation Regulations (FARs), greatly affect advanced vertical flight aircraft performance characteristics and, therefore, the facility requirements of vertiports and large heliports. In order to develop realistic facility design criteria, a number of questions need to be answered.

1. Will FAA certify new aircraft to perform maneuvers that conventional rotorcraft are not currently certified to execute, such as:

    - steep (9-degrees or greater) instrument approaches, particularly to Category III minimums (0 foot ceiling and 600 feet visibility runway visual range (RVR),

    - slow instrument approaches (30 knots or less) and instrument meteorological conditions (IMC) hovers, and

    - unrestricted vertical climbs and descents in both visual meteorological conditions (VMC) and IMC with no height-velocity curve restrictions?

2. What will the OEI procedures be, as well as requirements for rejected takeoffs (RTO) and landings?

3. What will be the tradeoff in terms of payload and range for vertical versus short takeoff and landing (STOL) procedures?

4. What horizontal takeoff distance (including clearing a 35 foot obstacle) will be required for balanced field length at 100 percent maximum gross takeoff weight (MGTOW) for various density altitudes?

5. What will be the separation criteria between different sizes of aircraft for wake turbulence avoidance?

The answers to these questions clearly affect facility design issues such as the size, location, and number of touchdown and lift-off surfaces (TLOF), final approach and takeoff areas (FATO), and imaginary airspace surfaces around large heliports and vertiports. In fact, the introduction to the FAA's AC "Vertiport Design" states:

> The standards in this AC are based on the assumptions that manufacturers will develop a tiltrotor aircraft and navigational equipment with the demonstrated redundancy of performance to safely: (1) fly a 9-degree approach path during instrument meteorological conditions with an accuracy warranting reduced airspace, (2) decelerate to zero velocity prior to reaching the touchdown point, (3) transition from an instrument flight environment to visual environment before reaching the touchdown point, and (4) eliminate the necessity for missed approach areas and surfaces which differ from the areas and surfaces required for the approach.
>
> A tiltrotor aircraft with navigational equipment and certified capabilities to operate safely and efficiently within the airspace recommended by this AC - with a sustained safety level commensurate with airplane operations - will have to be developed by industry to obtain the desired operating minimums.

Differences as well as similarities between conventional rotorcraft and advanced aircraft, as they apply to vertiport and large heliport design criteria, are highlighted in this effort.

In developing vertiport requirements for this report, the operating characteristics of conventional rotorcraft and the CTR are compared in terms of facility design requirements. Although they are both vertical takeoff and landing (VTOL) aircraft, helicopters and CTRs do have significantly different operating characteristics that affect facility design criteria. These differences include their physical size and weight, payload, missions served, fuel capacity, as well as their normal and emergency performance capabilities.

One of the single greatest differences between helicopters and the CTR is that the FAA has certified a large number of conventional rotorcraft and has clearly defined their performance limitations in FAA-approved rotorcraft flight manuals. As of mid-1994, however, FAA has not certified any CTR or other powered-lift aircraft (see section 2.5). Bell-Boeing recently indicated that the 40-passenger CTR will not be on the market before the year 2005, at the

earliest (reference 4). The FAA's CTR certification process is therefore presently on hold. The Europeans are actively developing a CTR, EUROFAR which is still in the preliminary design phase. The consortium of aerospace firms working on the EUROFAR program do not anticipate certification of their CTR before the year 2009.

FAA certification of the CTR was initiated under an interim regulation for powered-lift transport category aircraft (see section 2.5), which includes tiltrotor, tiltwing, fan-in-wing, and vectored thrust aircraft. Exactly how application of this new proposed regulation will impact actual CTR performance characteristics has yet to be determined.

The V-22 Osprey tiltrotor has been undergoing test and evaluation for acceptance by the U.S. Marine Corps. However, the Osprey's performance characteristics will not be the same as a civil aircraft. The V-22 is specifically designed for a military mission, and the Osprey has many features that the proposed civil version will not have such as armor, self-sealing fuel tanks, folding wing and rotors, etc.

Much of the information concerning anticipated CTR performance is presented in, the Civil Tiltrotor Development Advisory Committee Report to Congress (reference 3), NASA's two missions and applications studies (references 5 and 6), and associated data packages prepared by Bell-Boeing. The two NASA reports were based on conceptual designs and data interpolated from the XV-15 and V-22 programs, from which a whole family of CTR aircraft was developed (see figures 1 through 3). The CTR-22C represented an early idea of what a civil variation of the V-22 might be. It was envisioned as a 39-passenger, pressurized aircraft, potentially the first CTR to be developed by Bell-Boeing. However, the issue of CTR design is being re-examined. This process is likely to continue until the turn of the century or beyond.

The majority of vertiport feasibility studies prepared by the 13 locations around the country used the conceptual CTR-22C configuration as a basis for their analyses. Therefore, due to the available database and to maintain commonality with previous vertiport studies the CTR-22C is also used for the purposes of this research report. Assumptions concerning the CTR-22C's performance characteristics are presented when used in this report, recognizing that all of the data needed is not presently available. The use of the CTR-22C as the basis of these research efforts highlights a unique situation, namely, that numerous economic feasibility studies and detailed facility design criteria are being developed for an aircraft that does not exist except in concept.

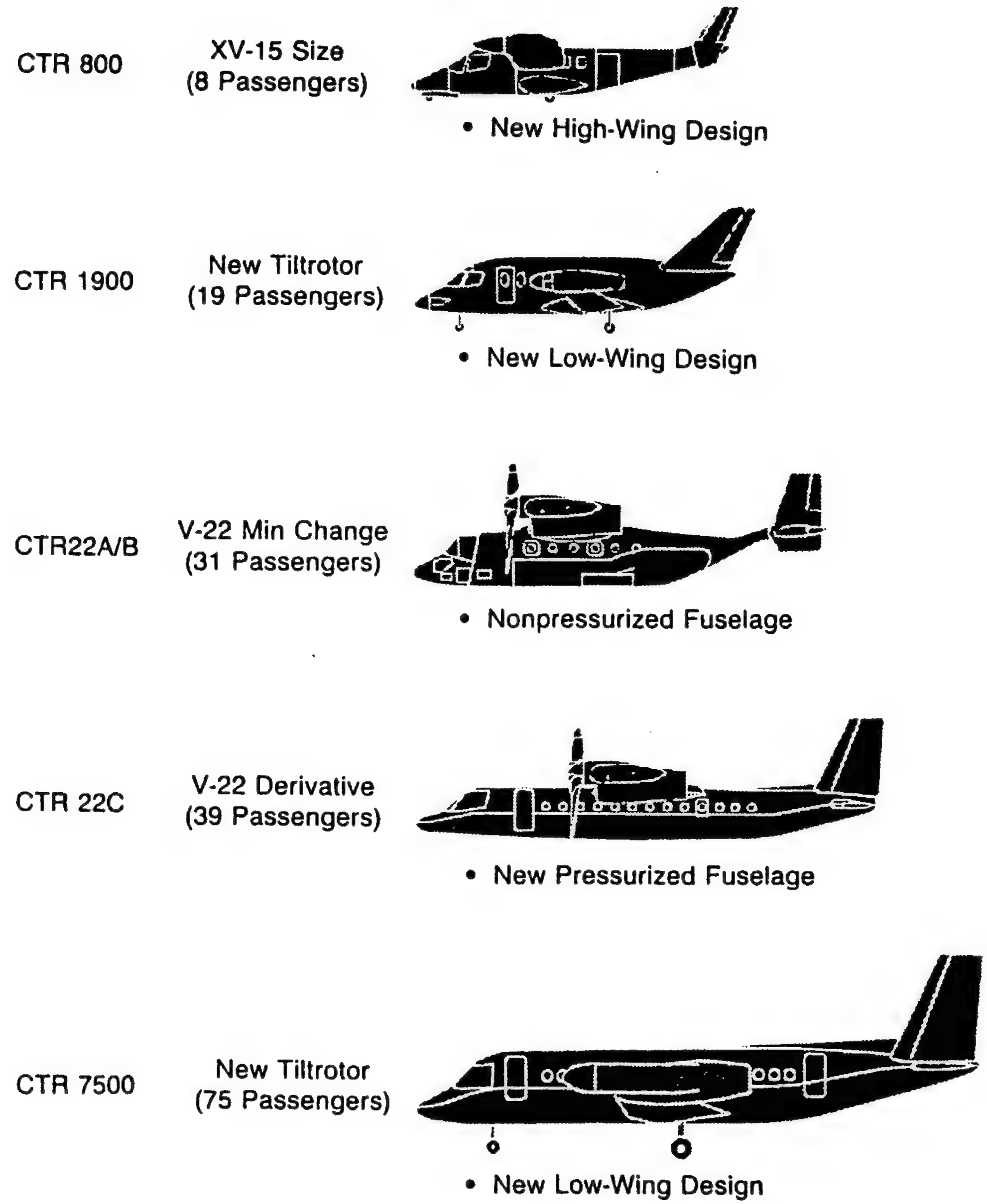
It should be noted that the CTRDAC has used the 40-passenger CTR-2000 as their design aircraft. This was based on the CTRDAC's conclusion that the CTR-22C would NOT be an appropriate aircraft for introduction into civil use (reference 3). However, the analysis documented in this technical report was well underway when the CTR-2000 design concepts were advanced. Funding was not available to update this report to be consistent with the findings of the CTRDAC report.

Tiltrotor Configurations

Civil Tiltrotor configurations developed for the study are shown to the left. One configuration, the CTR-800 is based on the XV-15 tiltrotor size; two configurations, the CTR-22A/B and CTR-22C are derivations of the V-22 military tiltrotor; and two configurations, the CTR-1900 and CTR-7500, are all-new civil tiltrotors. An additional derivative of the military V-22 tiltrotor, the CTR-22D, was developed to evaluate higher capacity and a more efficient fuselage cross-section.

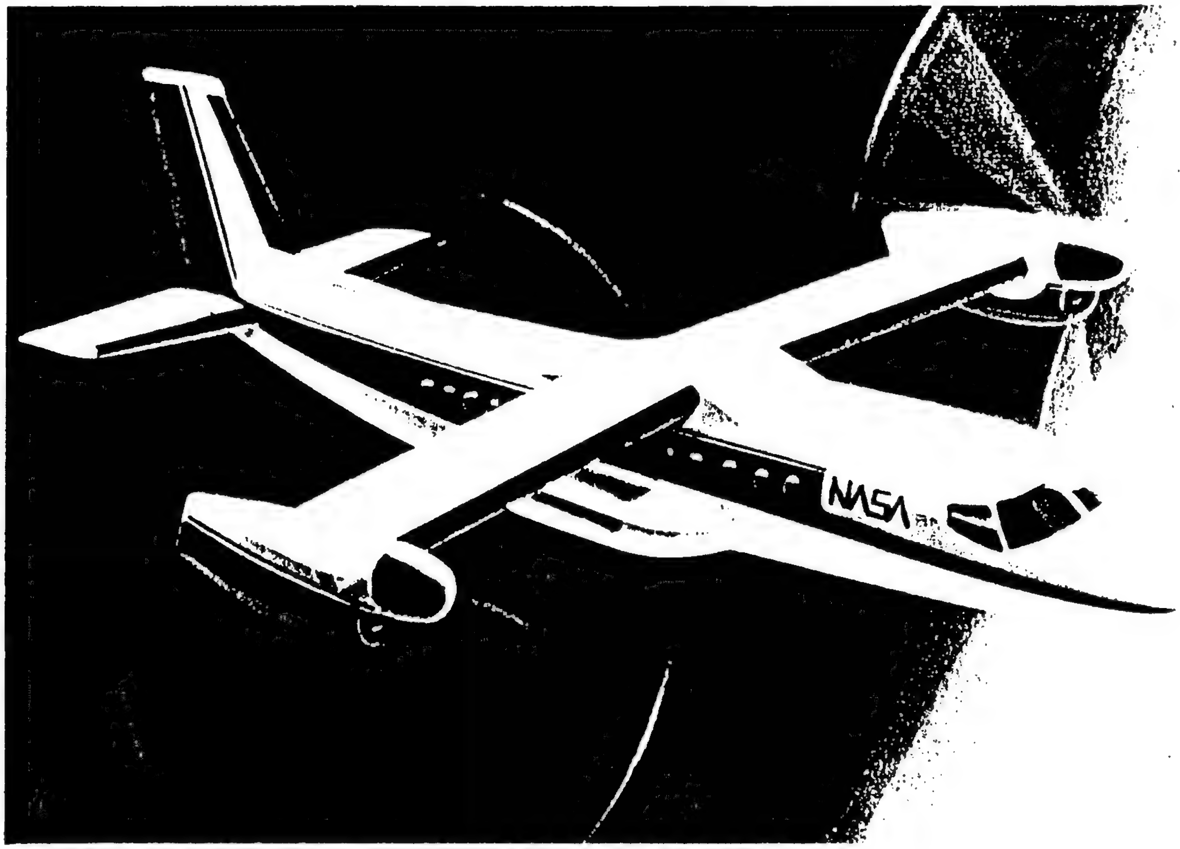
The design technology of the V-22 military tiltrotor drove the preliminary design of all the configurations. Guidance for civil tiltrotor design were developed by BCAC, Bell, and Vertol based on V-22 and commercial design experience. Specific modifications were based on federal aviation regulations and input from commercial operators.

The structural design concept and propulsion systems used on all the configurations are the same as the V-22 military tiltrotor; these include the twin-engine arrangement, rotors, controls, gearboxes, and driveshaft cross-shafting. Some modifications were needed, depending on the location of the auxiliary power unit and whether a high or low wing was used.



Source: Reference 7.

FIGURE 1 TILTROTOR CONFIGURATIONS



Vehicle Design Guidelines

- o V-22 derivative or technology base:
  - o twin engines
  - o composite airframe
  - o tilting wingtip mounted rotors
  - o fly-by-wire
  - o advanced cockpit displays
- o 600 nmi design range, vertical takeoff with one engine inoperative (OEI hover)
- o 800 nmi design range with rolling takeoff from 750 feet field (STOL)
- o Commuter mission profile with FAR reserve fuel requirements
- o All federal aviation regulations met for safety, including Category A operations
- o Ramp self-sufficiency; airstairs, APU, powerback
- o Helicopter NPRM for 30 sec emergency power rating assumed
- o Pressurized fuselage
- o Normal passenger accommodations and amenities:
  - o seating at 30 in pitch
  - o lavatories and galley (hot meal with beverage)
  - o full cabin heating and air conditioning
  - o pressurization desired

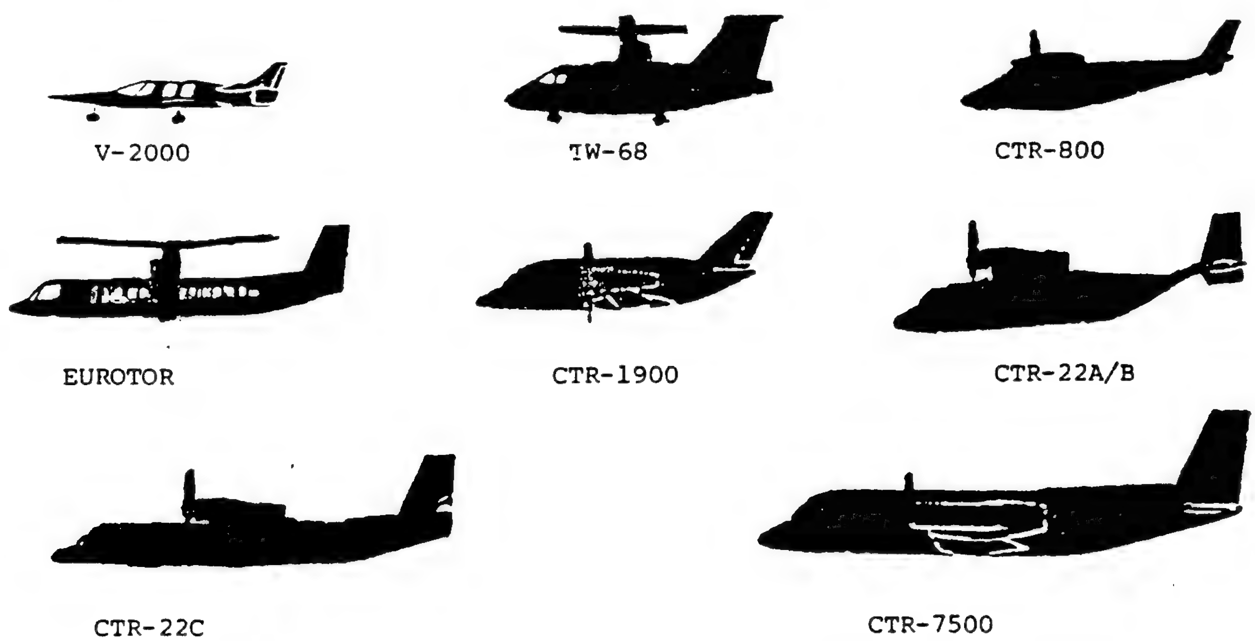
Source: Reference 7.

FIGURE 2 VEHICLE DESIGN GUIDELINES

NOTE: ALL DIMENSIONS ARE APPROXIMATE

MODEL	WEIGHT POUNDS	SPAN TIP-TIP FEET	ROTOR DIAMETER FEET	OVERALL LENGTH FEET	HEIGHT FEET	LANDING GEAR TREAD FEET	LANDING GEAR WHEELBASE FEET	NUMBER PASSENGERS
V-2000*	4,500	29	4 F.D.	32	10	7	14	6
TW-68**	16,500	41	17	39	13	9	15	11-16
CTR-800	15,750	58	26	41	15	8	15	8
EUROFAR	18,000	76	33	52	20	13	28	19
CTR-1900	22,800	65	28	47	17	13	20	19
EUROFAR	36,000	86	36	65	21	13	28	30
CTR-22A/B	45,120	85	38	57	18	15	22	31
CTR-22C	46,230	85	38	69	21	11	30	39
CTR-22D	49,260	86	38	72	23	11	30	52
CTR-7500	79,820	109	46	84	28	17	28	75

* Fan-in-wing F.D. Fan Diameter
** Tilt-wing



Source: Reference 2.

FIGURE 3 TILTROTOR AIRCRAFT DATA

Another proposed advanced vertical flight aircraft, the Sikorsky S-92 shown in figure 4, was conceived to serve both the civil and military market. In its civilian role, the S-92 could hold 30 passengers and have full instrument flight rules (IFR) capability. Combining new technology with elements from the successful UH-60 Blackhawk helicopter, the S-92 is still being studied by Sikorsky regarding its economic feasibility. Sikorsky has announced that they are committed to the development of the S-92. Although there are no launch customers at this time, the S-92 is scheduled to fly in 1998 or 1999 with first delivery taking place sometime after the turn of the century.

Yet another new advanced vertical flight transport aircraft, the three engine EH-101 shown in figure 5, is flying at present. It is being developed by E.H. Industries, a consortium formed by Agusta and Westland Helicopters, Ltd. Nine pre-production aircraft have been produced and are flying, and orders for the EH-101 have been placed by both the British and Italian armed forces. It also is designed to carry 30 passengers with full IFR capability. It is being marketed for both scheduled service and off-shore support roles.

However, there have been no orders for the EH-101 from either military or civilian operators in the U.S. Although it is currently available, it has not caught the imagination of aviation enthusiasts or planners in the United States, as have CTRs. There has been no public initiative to develop civil transportation systems for the EH-101 in the United States.

1.1.2 IFR Design Assumption

The airspace required for precision approaches has been a significant impediment to heliport development in urban areas, and as a consequence, no public-use heliport in the U.S. has a precision instrument approach. For the purposes of this analysis a basic assumption was made regarding the airspace requirements for precision approaches to heliports and vertiports, which was based on an airspace model for a microwave landing system (MLS). MLS criteria are used in this study for two reasons.

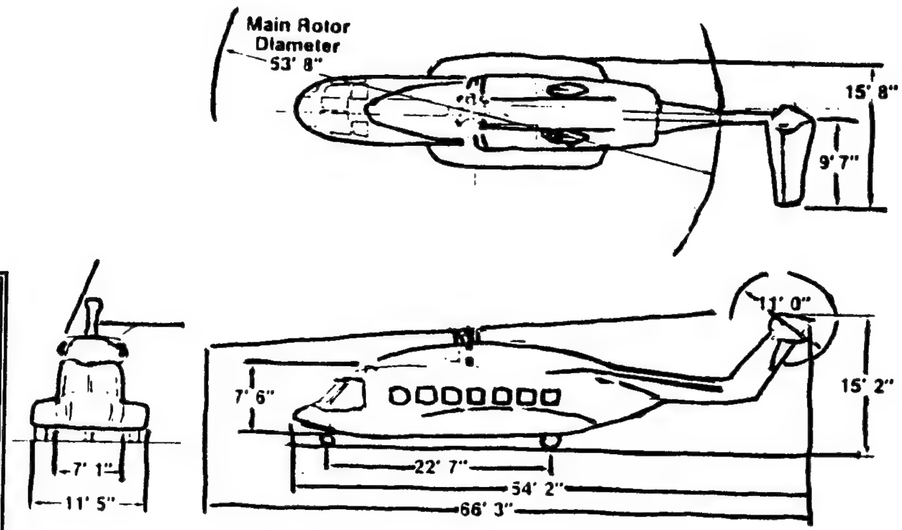
- Heliports and vertiports that provide scheduled passenger service to city centers, where airspace is congested and considered a scarce resource, will require precision approaches. MLS criteria require a minimum of airspace as compared to other currently approved precision and non-precision approach criteria.

- In order to achieve maximum benefits at a heliport or vertiport, vertical flight aircraft must provide safe and reliable service. In order to provide this service, precision approach capability utilizing the vertical flight aircraft's steep approach capability will be needed. The differential global positioning system (dGPS) is expected to provide this capability in the not-too-distant future. However this was not the case at the time that this study was initiated. Thus, MLS criteria were used in the development/ analysis of steep-angle approaches to vertiports.

Sikorsky S-92

Civil Transport

The S-92 was announced in 1992 as the concept of the premier medium civil helicopter for the turn of the century and beyond.



	English Units	Metric Units
Performance		
Sea Level, ISA, 22,220 lb		
- Maximum cruise speed	160 kts	296 km/hr
- Best range speed	140 kts	259 km/hr
- OEI service ceiling	7,000 ft	2,100 m
- Hover, OGE	6,500 ft	1,980 m
- Hover, IGE	10,800 ft	3,290 m
- Range	400 nm	741 km
(at V_{BE} + 10% reserve)		
Weights		
- Takeoff gross weight	22,220 lb	10,808 kg
- Empty weight	13,730 lb	6,230 kg
Cabin		
- Normal seating	19	19
- Width	6 ft	1.83 m
- Height	6 ft	1.83 m
- Volume	596 ft^3	16.87 m^3
- Baggage volume	168 ft^3	4.76 m^3
Engines		
Proposed minimum ratings		
- Twin engine, takeoff	1,750 shp	1,305 kw
- Maximum continuous	1,450 shp	1,081 kw
- OEI, 30 second	2,200 shp	1,641 kw
- OEI, 2 minute	1,950 shp	1,454 kw
- OEI, 30 minute	1,750 shp	1,305 kw

March 1992

Profitability through low DOC and high reliability
- Proven BLACKHAWK and SEAHAWK systems
- GE CT-7 or RTM-322 engines
- Maintainability by design

Designed for mission performance
- North Sea offshore oil
- Gulf of Mexico/tropical offshore oil
- Airline
- Bulk cargo
- Search and rescue
- VIP

Safety
- Designed to FAA/CAA/JAR requirements
- Category A/JAR Group 1 performance
- Redundant systems
- Crash resistant, suction fuel system
- HUMS
- Internal flotation, emergency lighting and raft systems

UNITED TECHNOLOGIES SIKORSKY AIRCRAFT

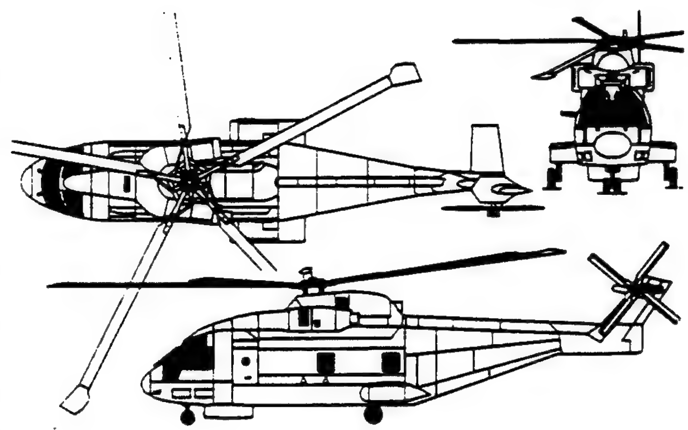
Source: Sikorsky Aircraft.

FIGURE 4 SIKORSKY S-92

EH101

Dimensions
External

Main rotor diameter	(61ft 0in)	18.6m
Tail rotor diameter	(13ft 2in)	4.0m
Length overall, both rotors turning	(74ft 10in)	22.8m
Width, excluding main rotor	(14ft 10in)	4.5m
Height overall, both rotors turning	(21ft 10in)	6.7m
Crew doors (fwd, part)		
Height	(5ft 7in)	1.7m
Width	(3ft 0in)	0.9m
Rear loading ramp/door		
Height	(5ft 11in)	1.8m
Width	(6ft 11in)	2.1m



Vne
167 knots EAS (309 km/hr, 193 mph)

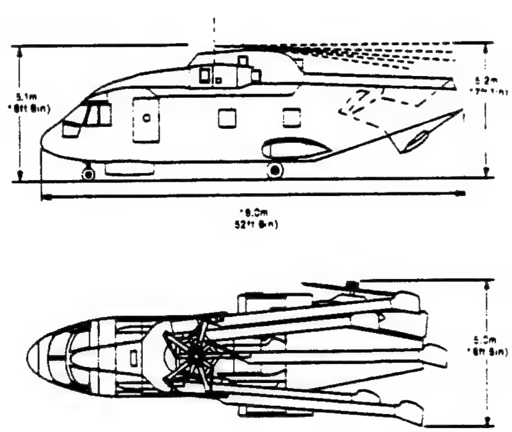
Typical cruise speed
150 knots TAS (278 km/hr, 173 mph)

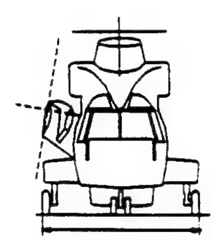
Best range cruise speed
150 knots TAS (278 km/hr, 173 mph)

Range
Range with zero take off distance
(category A rules)
300 nm (610 km, 380 miles)

Max ferry range
950 nm (1760 km, 1093 miles)

Engines
3 Rolls Royce Turbomeca RTM 322





Source: E.H. Industries

FIGURE 5 EH-101

Since the time that this analysis was conceived, much has taken place concerning IFR landing systems. The FAA has canceled their MLS program and intensified their GPS program. Data collection for the development of rotorcraft non-precision approach terminal instrument procedures (TERPS) was completed in November 1994. A data collection effort for rotorcraft Category 1 precision approach TERPS is scheduled to start in the summer of 1996. GPS is far superior to MLS for heliports and vertiports. Both the increase in accuracy and the decrease in cost are powerful improvements. Rotorcraft GPS TERPS airspace is likely to be somewhat smaller than what was proposed several years ago for collocated MLS TERPS.

2.0 EXISTING LARGE HELIPORT AND VERTIPORT DESIGN CRITERIA

2.1 INTRODUCTION

This section summarizes existing design criteria published by the FAA relating to the development of large heliports and vertiports. The FAA has undertaken a significant amount of research into the operational characteristics of rotorcraft, particularly as they relate to heliport design criteria. It is not the intention of this study to duplicate those efforts. An excellent summary of those research programs is presented in a report developed by the FAA's Vertical Flight Program Office, "Safe Heliports Through Design and Planning" (reference 8).

Based on the data presented in the FAA's report, it is clear that the optimum design criteria for heliports and vertiports have not yet been fully developed, neither from the FAA's nor the rotorcraft industry's perspective. Part of the challenge in developing appropriate design criteria is the conflict between the need to minimize real estate and airspace requirements in order to provide access to urban areas, with their obstacle-rich environments and high property values, versus the need to provide an adequate safety margin. Reference 8 concludes:

> During the 1984-1988 time period, the FAA revised the 1977 Heliport Design AC. In discussions on proposed changes, industry recommended that the FAA "be more objective" in their decision making on heliport design issues. The FAA accepted this advice and initiated a number of research efforts in response. The majority of these efforts are now complete. Thus judgements can be made on where changes are appropriate and where additional study is required.
>
> The Heliport Design advisory circular should strike a balance between safety and economics. Decisions on the contents of such an AC are not based on technical input alone. Design criteria have economic and political consequences and these issues must be considered. Technically, it is clear that many of the minimum requirements in the 1988 Heliport Design AC are inadequate. Politically and economically, other arguments can be made.

A number of recommendations that were presented in the FAA's report (reference 8) concerning heliport design criteria are explored in this study. A key difference between heliport and vertiport design criteria is, of course, the fact that a significant amount of helicopter operational experience and test data are available, while there is no corresponding database for the CTR operating at vertiports.

2.1.1 Sources of Design Criteria

The analysis presented in this research effort draws upon a variety of published sources relating to heliport and vertiport design, in addition to applying pertinent data from airport

design criteria. The goal of this effort is to develop conceptual large heliport and vertiport facility design criteria that incorporate the results of the research performed to date, and to extract data and experience from airports where it is relevant to do so.

Recognizing that there are significant differences between fixed-wing and VTOL aircraft operating characteristics, the reasons that airport design criteria are used as a basis for comparison to large heliports and vertiports are explained below:

- Airport design criteria have evolved over a long period of time based on extensive operational experience. Current airport criteria reflect the results of incorporating that database into the design standards, which is one of the goals of the research and development (R&D) being conducted by the FAA into heliport/vertiport design. It is the process by which aircraft performance data are translated into facility design criteria that is relevant to heliport and vertiport design.

- There is an enormous existing database of airport design criteria, some of which are directly applicable to heliports and vertiports. As described in more detail below, both the heliport and vertiport design guides presently incorporate a variety of airport-related specifications by direct reference in the ACs.

- Large heliports and vertiports, are expected to generate the type and volume of scheduled airline traffic that fall within the jurisdiction of regulations that presently apply to airports, such as 14 CFR 107 Airport Security, and 14 CFR 139 Certification and Operation: Land Airports Serving CAB Certificated Carriers. These regulations can significantly impact heliport and vertiport design criteria.

Airport design criteria are used in vertiport/large heliport design for elements that are relevant to both types of facilities, for example, elements that would be needed in vertical flight passenger systems such as aircraft gates baggage handling, terminal facilities, etc. It is recognized that, ultimately, specialized "vertical flight only" designs for these elements may make sense. However, until experience and operational issues define such a need, it makes more sense, both operationally and financially, to base prototype designs on tested fixed-wing/airport experience. Airport criteria will also be used for comparisons and recommendations in areas where expanded vertical flight passenger service may ultimately require the same limits, controls, or regulations as fixed-wing services.

2.1.2 Federal Authority

The FAA derives its authority to promulgate design standards for heliports and vertiports from Congress, as spelled out in the Federal Aviation Act of 1958 (P.L. 85-726). As noted in Section 103 of that Act:

DECLARATION OF POLICY: THE ADMINISTRATOR

Sec. 103. In the exercise and performance of his powers and duties under this Act the Administrator shall consider the following, among other things, as being in the public interest:

(1) The regulation of air commerce in such a manner as to best promote its development and safety and fulfill the requirements of national defense.

(2) The promotion, encouragement, and development of civil aeronautics.

(3) The control of the use of the navigable airspace of the United States and the regulation of both civil and military operations in such airspace in the interest of the safety and efficiency of both.

The roots of the "safety versus cost" debate in heliport planning and design can be traced directly to the language in the 1958 Act. The FAA is charged with both the regulation of air commerce as well as the promotion and encouragement of civil aeronautics. That same debate regarding airport design criteria has been largely resolved, in part because airport design criteria are based upon well-documented aircraft performance characteristics. The relationship between rotorcraft performance and facility design, however, has not been as clearly defined, as discussed in more detail in the following sections.

2.1.3 State and Local Standards

It must be stated that the FAA ACs are just that -- *advisory*. The standards are not mandatory unless Federal money is accepted. Due to the fact that it would not be cost-effective for state or local governments to develop their own heliport/vertiport standards, most state and local governments rely on Federal standards. However, it is important to note that a number of states, such as Pennsylvania, California, and Florida, have published design standards that are mandatory for facilities receiving state financial assistance.

In addition, some municipalities that license aviation facilities within their jurisdiction (e.g., New York City) have also developed design criteria. Needless to say, this is not a common practice, since most municipalities rely on state and/or Federal criteria to determine compliance for licensing or permitting requirements. This study does not analyze individual state and municipal requirements even though some have issued their own airport and heliport design criteria.

2.2 LARGE HELIPORT AND VERTIPORT DESIGN AND CLASSIFICATION ISSUES

The FAA disseminates its design criteria for airports, heliports, and vertiports, primarily through ACs but also through orders and Fads, as well as by reference to consensus setting (non-regulatory) agencies such as the National Fire Protection Association (NFPA). ACs

serve as the primary vehicle for disseminating airfield design standards, because they provide much greater flexibility in terms of revisions and updates than do regulations and orders, as well as the flexibility to address a very wide variety of detailed design issues. ACs are issued "to inform the aviation public in a systematic way of non-regulatory material of interest." See appendix A for a more detailed description of the AC system.

As noted in (reference 8): "An advisory circular is NOT intended to be a mechanism to aid people in justifying what they have been doing in the past. It is intended to be a document that describes standards, recommendations, and guidance for what they should be doing in the future." The criteria represent minimum design standards, which means that facilities can exceed the criteria shown in ACs, for instance, greater separation distances between facilities, larger FATOs and TLOFs, protection of larger imaginary surfaces, etc.

The criteria presented in FAA ACs are advisory in nature; as their title implies, the standards only become mandatory when the sponsor receives Federal grant-in-aid assistance. Sponsors receiving Federal aid can plan and design to higher standards than the AC, but in no case can they ignore or plan to lower standards that those contained in the AC.

A number of municipalities and states, however, require that privately-owned, private-use heliports meet FAA design criteria as a condition of receiving a permit to build and operate a heliport. That is a local, not a Federal regulation. The FAA specifically acknowledges local jurisdiction over land-use controls (so-called "home rule"), including issuing permits or licenses for heliports and airports.

2.2.1 Design Characteristics Considerations

Heliports and vertiports share a number of common design characteristics, such as the FATO and TLOF. The current standards contained in the heliport and vertiport design ACs (references 1 and 2) are summarized in table 2.

It can be seen from the table that the sizes of heliport and vertiport primary operational areas, namely the FATO and TLOF, are predominantly based on the physical dimensions of critical aircraft, NOT the performance characteristics of the aircraft. The exception to this is the recommendation to increase the size of the FATO as the elevation of the facility increases above 1,000 feet mean sea level (MSL). In addition, the AC "Vertiport Design" specifically states: "An elongation of the TLOF up to 400 feet offers significant operational and economic benefits and is recommended whenever site conditions permit."

However, no reference is made in either AC to the takeoff, climb, or engine-out performance requirements of any specific rotorcraft or tiltrotor aircraft. By contrast, airport design criteria (reference 9) are based primarily on aircraft performance characteristics, particularly for runway length and operational capacity requirements.

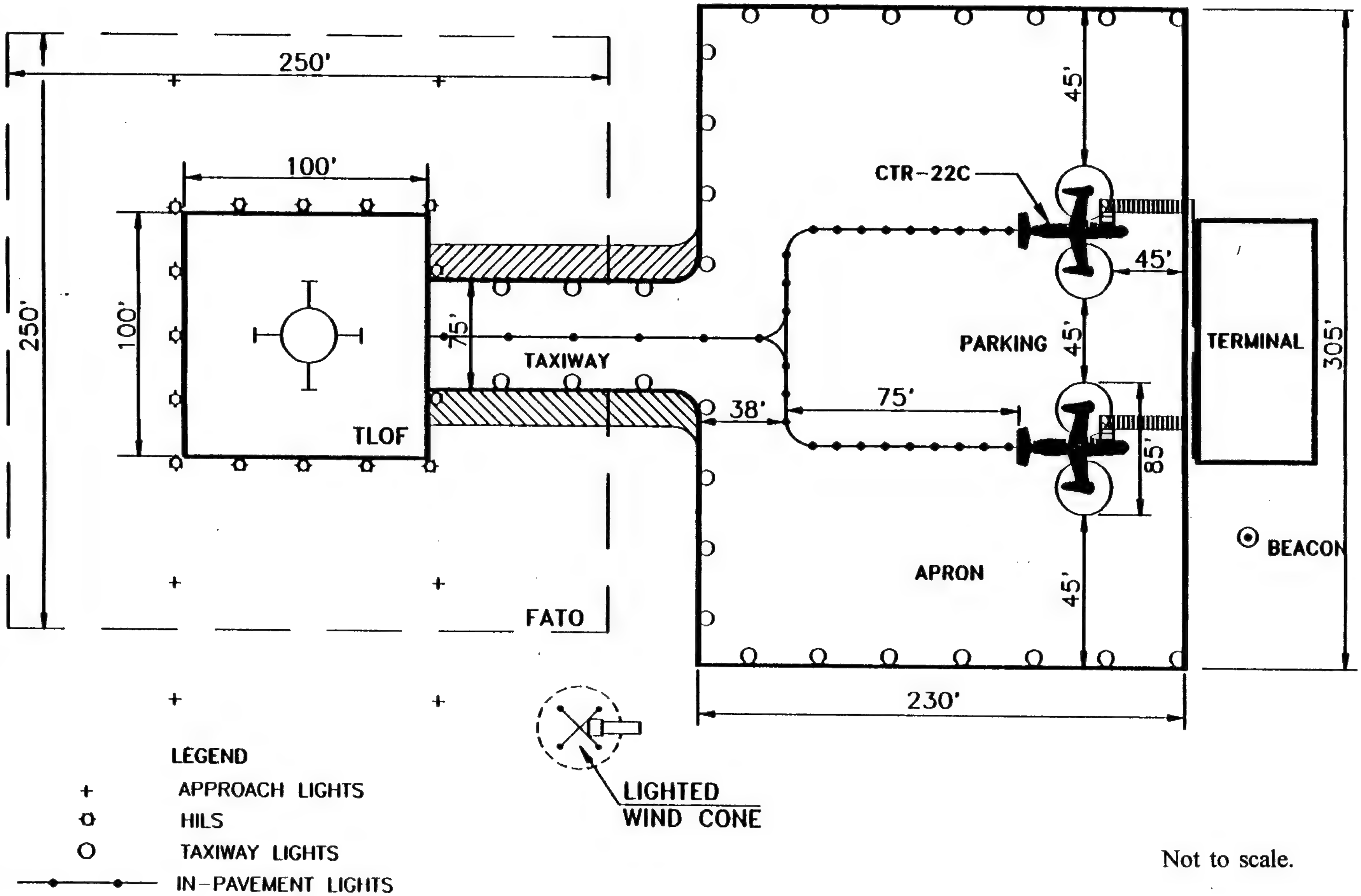
It is interesting to note in table 2 the significant increase in size of the FATO for precision instrument approaches to both heliports and vertiports. However, the increase is NOT due to performance requirements such as acceleration or RTO procedures for the CTR, but is designed to accommodate the heliport approach lighting system (HALS) that consists of 10 rows of light bars spaced 100 feet apart (see also section 2.4.2). Figures 6 through 9 illustrate the recommended heliport and vertiport design criteria as presented in FAA's advisory circulars.

TABLE 2 SUMMARY OF FAA DESIGN CRITERIA

DESIGN ELEMENT/SERVICE TYPE	VISUAL	NONPRECISION	PRECISION
FOR COMMERCIAL SERVICE HELIPORTS			
FATO [1]	200 ft x 100 ft	200 ft x 100 ft	1,225 ft x 250 ft
TLOF [1]	60 ft x 60 ft	60 ft x 60 ft	150 ft x 150 ft
APPROACH - Length - Slope	 4,000 ft 8:1	 10,000 ft 20:1	 25,000 ft 17:1 [3]
TRANSITIONAL	2:1	4:1	7:1
SUMMARY OF FAA DESIGN CRITERIA FOR VERTIPORTS			
FATO	250 ft x 250 ft	300 ft x 300 ft	1,225 ft x 300 ft
TLOF [2]	100 ft x 100 ft	150 ft x 150 ft	150 ft x 150 ft
APPROACH - Length - Slope	 4,000 ft 8:1	 5,000 ft 20:1	 25,000 ft 17:1 [3]
TRANSITIONAL	2:1	4:1	7:1
[1] Based on size of critical design aircraft Minimum size allowed shown. [2] Recommended length 400 ft where feasible. [3] Based on a 6-degree glideslope. Vertiports can achieve a 10:1 slope (9-degree).			

Sources: Reference 1 and 2.

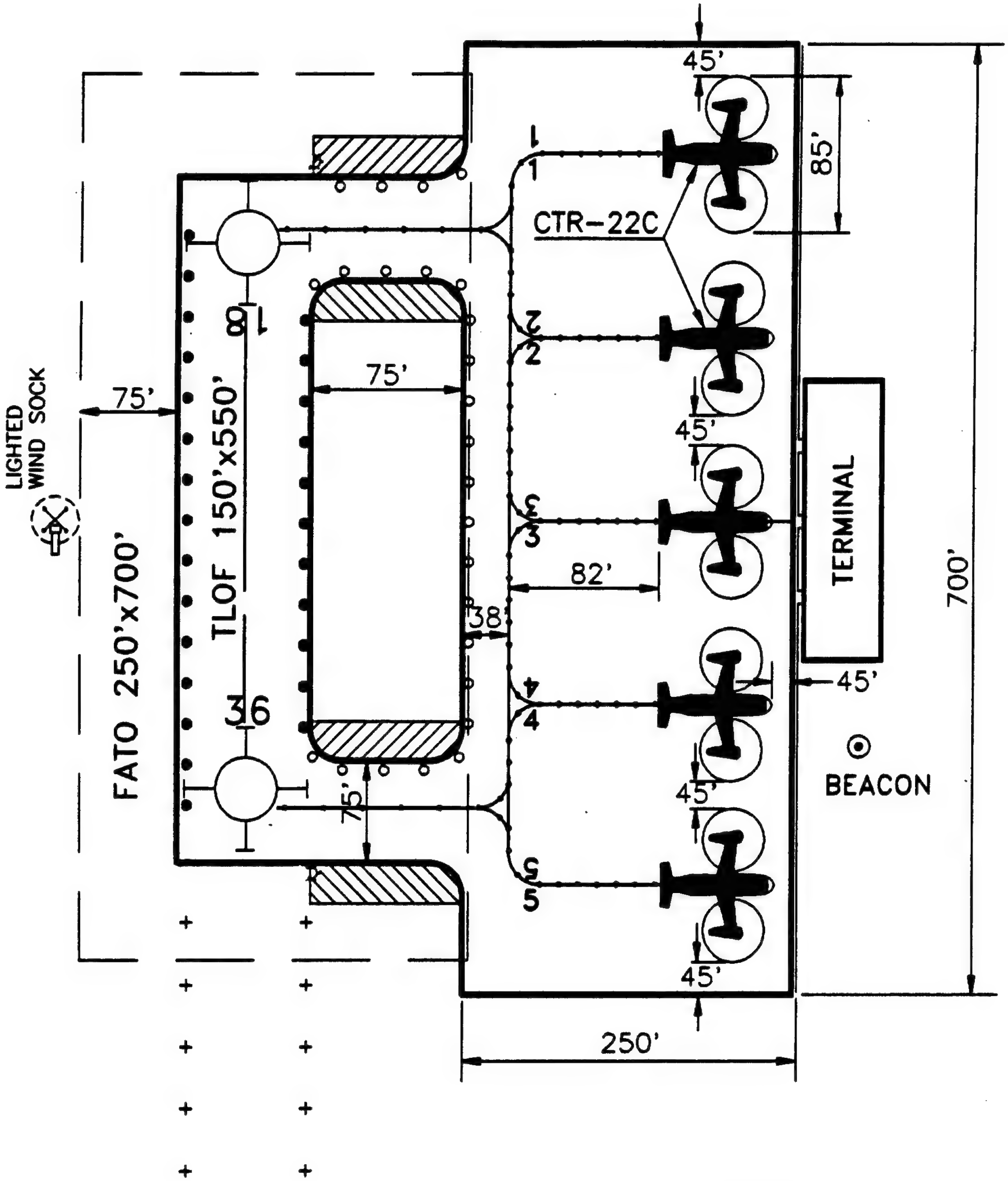
To further justify the need to consider CTR performance characteristics in facility design, it should be noted that the single largest operator of helicopters, the U.S. Army, incorporates aircraft performance characteristics into its permanent heliport requirements. U.S. Army Technical Manual TM 5-803-4, "Planning of Army Aviation Facilities," (reference 10) recommends a minimum "runway" length of 450 feet, increased 10 percent for each 1,000 feet above 2,000 feet MSL and 4 percent for every 10-degrees above standard temperature, and a width of 75 feet. In addition, there is a 1,000 foot long takeoff safety zone under each approach zone.



Source: Hoyle, Tanner and Associates.

Not to scale.

FIGURE 6 SMALL GROUND LEVEL VERTIPORT CONCEPTUAL DESIGN

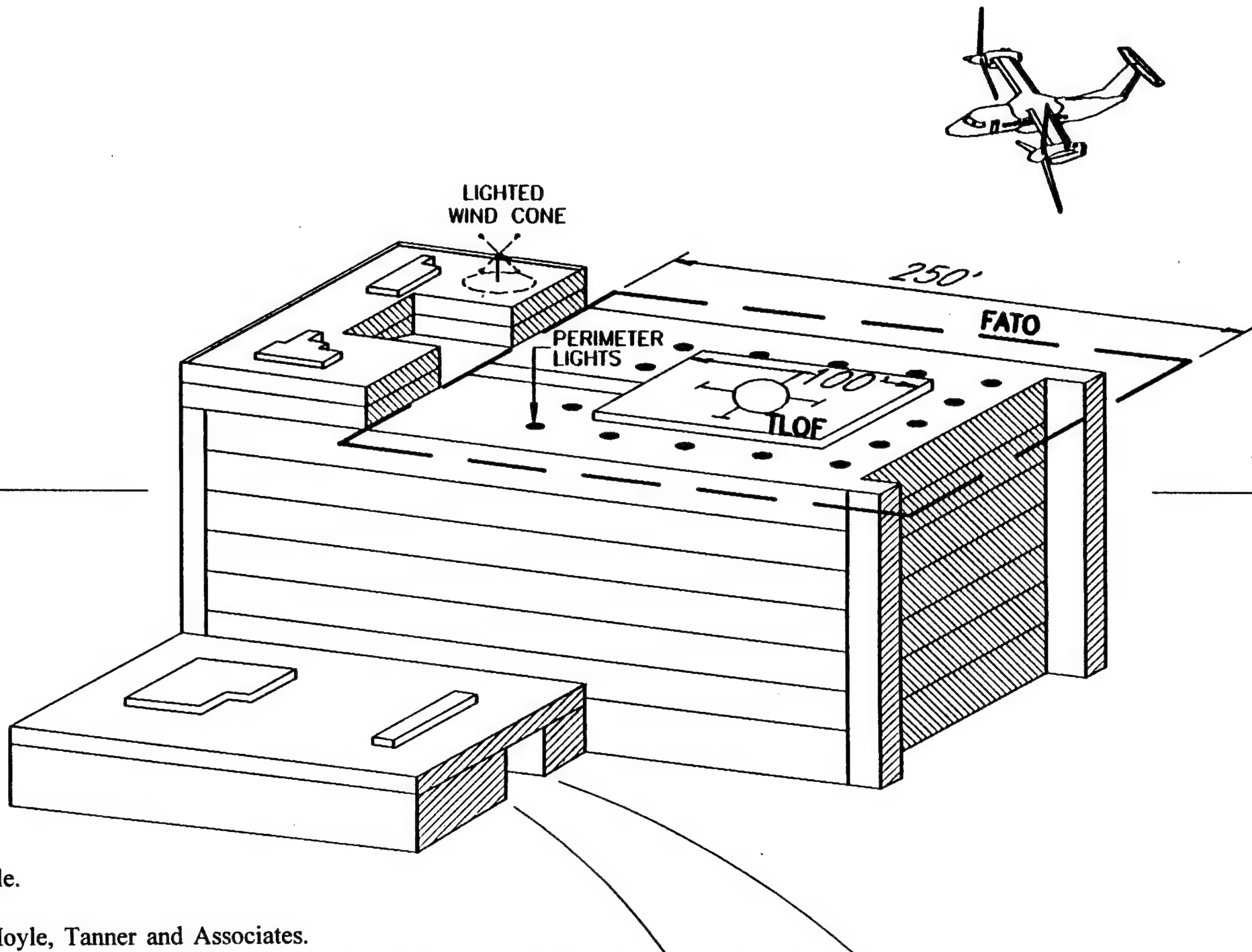


LEGEND
+ Approach Lights
• HILS
○ Taxiway lights
—•—•— In-Pavement Lights

Not to scale.

Source: Hoyle, Tanner and Associates, 1993.

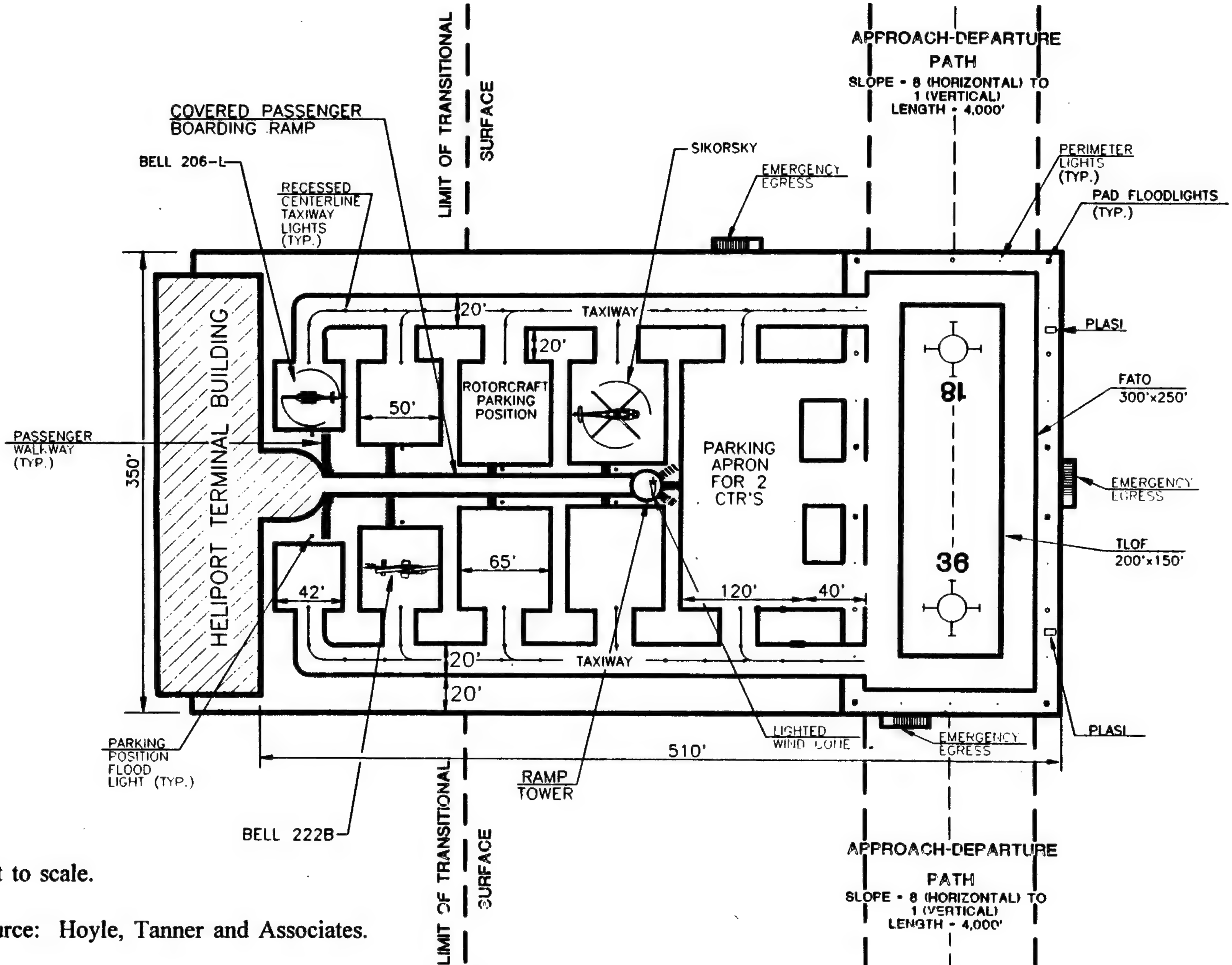
FIGURE 7 LARGE GROUND LEVEL VERTIPORT CONCEPTUAL DESIGN



Not to scale.

Source: Hoyle, Tanner and Associates.

FIGURE 8 ROOFTOP VERTIPORT CONCEPTUAL DESIGN



Not to scale.

Source: Hoyle, Tanner and Associates.

FIGURE 9 CONCEPTUAL ROOFTOP HELIPORT LAYOUT PLAN

2.2.2 Classification of Facilities

Another difference between airports and heliports is that heliports are not categorized by rotorcraft performance characteristics but by use and ownership. Heliports are classified by use (public or private); by level or type of service (general aviation, transport, or hospital); and by type of facilities (e.g., heliport or helistop). The focus of this analysis is on public-use, transport vertiports based on the expected role of advanced vertical flight aircraft (such as the EH-101, S-92, and CTR) in future transportation systems.

By contrast, airports are classified by the types of aircraft that use the facility, the type of services provided, as well as the operational and dimensional characteristics of the critical design aircraft. The FAA has a number of classifications for airports based on performance and use characteristics, such as: airport role (reliever, general aviation, and commercial service); airplane design group (ADG); and instrument approach (visual, nonprecision, and precision approach).

Another important airport design characteristic, the airport reference code (ARC), is used "to relate airport design criteria to the operational and physical characteristics of the airplanes intended to operate at the airport." Two characteristics in particular are utilized; aircraft approach category (based on approach speed, which affects runway length), and airplane design group (based on wingspan, which affects separation criteria). Airport design standards are based upon a "critical design airplane," which may in fact be a composite of several different aircraft. The critical aircraft represents the most demanding requirements in terms of approach speed, wingspan, wheel loading, and runway length. The ARC serves as a basic guide to determine which design criteria to apply, but it is primarily just a first step in that process. Detailed information about specific aircraft is required to determine runway length, pavement weight bearing capacity, and instrument approaches, as well as separation between taxiways, parking aprons, and terminal gates.

Because heliports and vertiports do not have the same type of functional classification as airports, they do not have design criteria based on aircraft performance as airports do (see table 3). The need for functional classifications and corresponding design criteria will increase as heliports and vertiports accommodate large advanced vertical flight aircraft (EH-101, S-92, CTR-22C, etc.), provide scheduled service, and increase in activity.

2.3 OPERATIONAL CONSIDERATIONS

There are a number of operational considerations that affect physical design. These include the location, number, and orientation of the TLOFs, FATOs and their associated approach surfaces; the operating capabilities of aircraft utilizing the facility (under various density altitude conditions); peak hour and annual demand; prevailing wind conditions (specifically crosswind limitations); noise abatement procedures; and aircraft parking apron and terminal building configurations and location relative to the FATO.

TABLE 3 COMPARISON OF AIRPORT AND HELIPORT/VERTIPORT CLASSIFICATIONS

CRITERIA	AIRPORTS	HELIPORT/VERTIPORT
CLASSIFICATION SYSTEM	Function (Use/type of aircraft/aircraft performance)	Facility Type & Use (Helistop/Helipad/Heliport Private-Public)
ROLE	G.A./Commercial Service/ Reliever	Utility/Transport
CATEGORY	Utility/Transport/Short-Medium-Long Haul*	Not Applicable
CAPACITY	Peak Hour/Annual Service Volume (ASV)	Not Applicable
AIRPORT REFERENCE CODE	Approach Speed/Wingspan (Design Group)	Not Applicable
AIRSPACE	VFR/IFR/Type of Approach	VFR/IFR

* National Plan of Integrated Airport Systems (NPIAS) Definitions (reference 11).
Source: Hoyle, Tanner and Associates, 1994.

Except for providing adjustments to FATO length based on site elevation, the heliport and vertiport design ACs provide little or no guidance on operational issues such as peak hour capacity or annual service volume (ASV); crosswind limits for helicopters or tiltrotors; TLOF/FATO dimensions required for acceleration to best rate of climb speed (V_y) under various weight, density altitude, and temperature conditions; or real estate to meet Category A balanced field length OEI requirements.

2.3.1 Category A Requirements

As aircraft such as CTRs are increasingly used for scheduled passenger service, one of the key issues regarding large heliport and vertiport design will be FATO length and the distance required to accelerate to a predetermined speed (such as translational lift, takeoff safety speed-V_{toss}, or best rate of climb speed-V_y) under various ambient conditions.

Some multi-engine rotorcraft certified under 14 CFR 29 can meet Category A requirements, which ensures the ability to either continue takeoff in the event of a single engine failure, or safely return to the landing site. Depending on gross weight and density altitude, some multi-engine helicopters can meet Category A requirements using standard helicopter takeoff procedures. However, many helicopters, when operating from a heliport with no acceleration area (i.e., a facility with a minimum size TLOF and FATO) must perform a vertical climb above and behind the TLOF until it is able to accelerate to V_{toss} over the landing site at an elevation of no less than 35 feet in order to meet Category A requirements. That procedure ensures the ability to either return to the landing site or continue the takeoff in the event of engine failure. It is NOT, however, a maneuver that is popular with either pilots or passengers, and in addition requires the ability to hover out of ground effect (HOGE), which is why it is actually used very rarely by pilots.

Category A requirements can also be met with a horizontal acceleration area of sufficient length that allows the helicopter to accelerate to V_{toss} (52 knots in an S-76A or 55 knots in

a Bell 212) at the critical decision point (CDP), which is 35 feet above field elevation. That procedure does not require the ability to HOGE, and therefore allows a higher gross takeoff weight and greater useful load to be carried under high ambient conditions. The "Heliport Design" AC does not make any reference to rejected takeoff (RTO) distance requirements for Category A rotorcraft.

2.3.2 Airfield Capacity

At commercial service airports, heliports, and vertiports, the issue of peak hour capacity and ASV is a critical element in identifying facility requirements, real estate requirements, and layout. Facilities such as runways, taxiways, parking aprons, and terminal gates are among the most crucial elements in determining capacity. In both the heliport and vertiport design ACs, the only reference to operational capacity is the statement that: "Multiple FATO's are recommended at public-use utility heliports anticipating 10 or more operations per hour" (reference 1, para. 22, p. 15).

Operational capacity is determined by a number of factors, such as minimum separation distance between aircraft on approach, average approach speed (either constant speed or decelerating approaches), TLOF occupancy time, weather conditions, distance between TLOFs located in the same FATO, separation between adjacent gates, and proximity to parking positions. Airport capacity techniques also account for differences in aircraft size (category); however, no such distinction has yet been made for conventional rotorcraft or CTR aircraft.

A detailed analysis of vertiport capacity issues and methods has been documented in FAA report FAA/ND-95/3, "Vertiport Capacity - Analysis Methods." At this point, this document defines the cutting edge of vertiport capacity analysis. However, in the absence of commercial CTR operational experience, several key parameters in this document rely upon the values estimated by experts. Thus, this work will need to be reexamined in years to come.

2.3.3 Simultaneous Operations

As scheduled passenger operations increase, a critical issue regarding airfield capacity will be the ability of vertical flight aircraft to make simultaneous approaches to two or more TLOFs located in the same FATO. This maneuver is similar in concept to simultaneous fixed-wing aircraft approaches to parallel or intersecting runways. Simultaneous approaches to intersecting runways for example, according to the FAA Order 7110.65H "Air Traffic Control" (reference 12), require an operating air traffic control (ATC) tower, visual weather conditions, dry runways, and specific concurrence by one of the pilots that they can and will hold short of the intersecting runway (reference 12).

Assuming that helicopters and CTRs can execute simultaneous approaches to and departures from two TLOFs within the same FATO, operational capacity can be increased significantly. According to the ATC handbook (reference 12), simultaneous helicopter

visual flight rules (VFR) departures and arrivals can be made to TLOFs separated by at least 200 feet, and flown on courses that do not conflict [chapter 3, section 11, Para 3-144].

A need to perform VFR simultaneous operations will also have an impact on real estate requirements. The "Heliport Design" AC states that a TLOF may be situated at each end of a single FATO if the FATO is at least 200 feet long. The AC, however, does not make any reference to simultaneous operations or to the ATC Order. If there were an operating control tower at the facility, simultaneous VFR operations to two TLOFs in a single FATO would require a FATO longer than 200 feet in order to meet the requirements in the ATC Order. TLOF layouts that accommodate independent and dependent VFR operations are depicted in figure 10.

Vertiport capacity concerns led the CTRDAC to consider the possibility of having two FATO's at a vertiport. However, simultaneous IFR operations would require that these FATO's be separated by 3,300 feet (along with other requirements). This separation requirements led to the conclusion that two vertiports would be more useful and more practical than one vertiport with two FATO's. The CTRDAC concluded that vertiports would be much larger than today's typical heliports, on the order of 20 to 30 acres or larger. However, the CTRDAC was skeptical whether much larger vertiports would be developed in order to support simultaneous IFR operations to two FATO's.

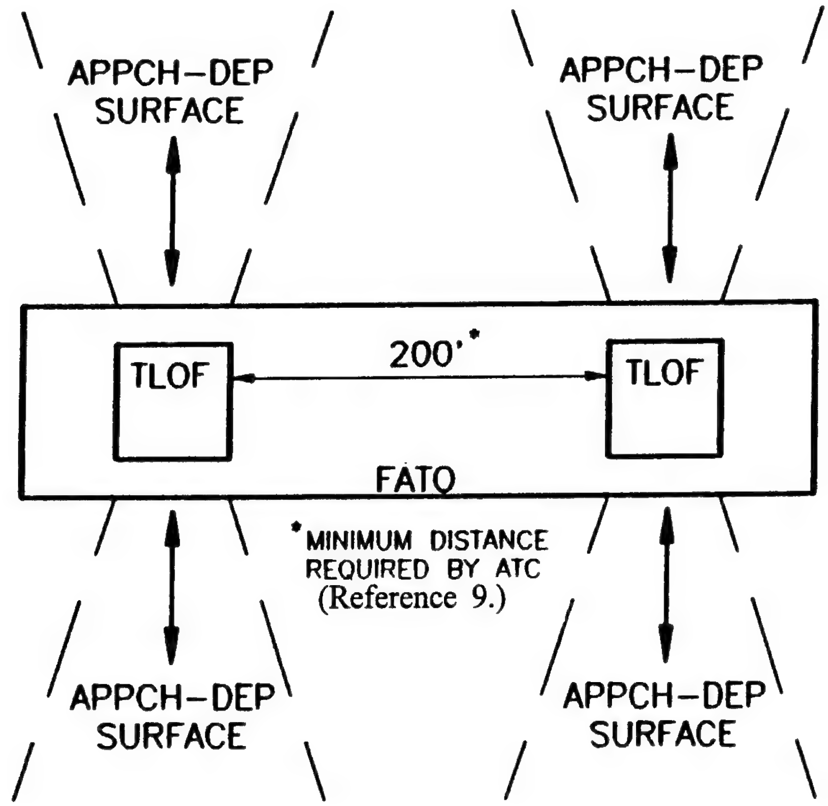
2.4 ROTORCRAFT PERFORMANCE CAPABILITIES

This section provides a summary of pertinent vertical flight aircraft performance characteristics that relate directly to heliport and vertiport design requirements. This analysis is based on published data and conclusions, and also highlights the areas that need further study in order to issue definitive facility design standards.

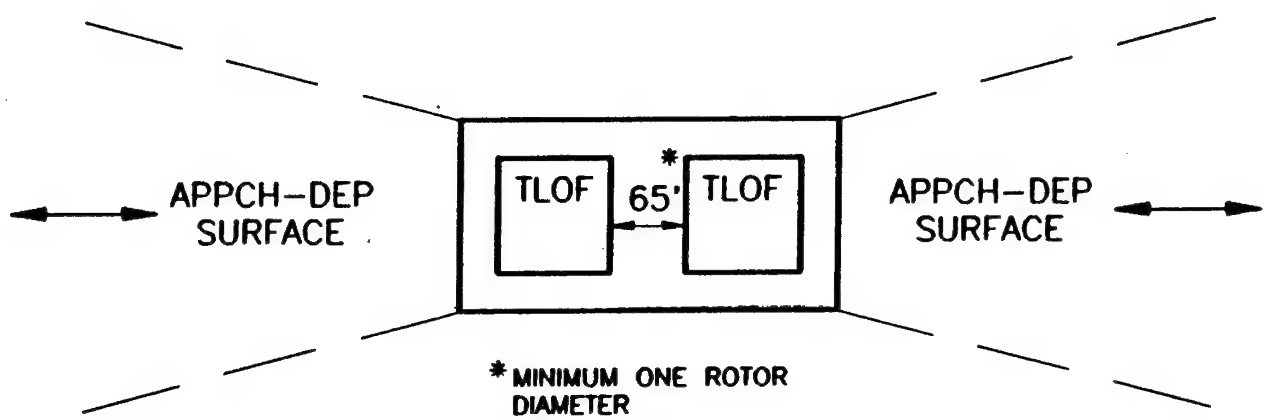
2.4.1 Performance Research

A number of studies were sponsored in the early 1980s by the FAA Systems Research & Development Service that examined rotorcraft performance characteristics as they affected heliport design criteria. Three studies prepared by PACER Systems, Inc. under contract to the FAA are particularly relevant:

- "Study of Heliport Airspace and Real Estate Requirements," FAA-RD-80-107; (reference 13)
- "Study of Helicopter Performance and Terminal Instrument Procedures," FAA-RD-80-58 (reference 14)
- "Development of a Heliport Classification Method and an Analysis of Heliport Real Estate and Airspace Requirements," DOT/FAA/RD-81/35 (reference 15)



A) INDEPENDENT SIMULTANEOUS VFR HELICOPTER OPERATIONS



B) DEPENDENT VFR HELICOPTER OPERATIONS

Not to scale. Source: Reference 13.

FIGURE 10 INDEPENDENT AND DEPENDENT VFR OPERATIONS CAPACITY OPTIONS

Subsequently, a series of studies was sponsored 10 years later by the FAA and prepared by SAIC that re-examined similar issues:

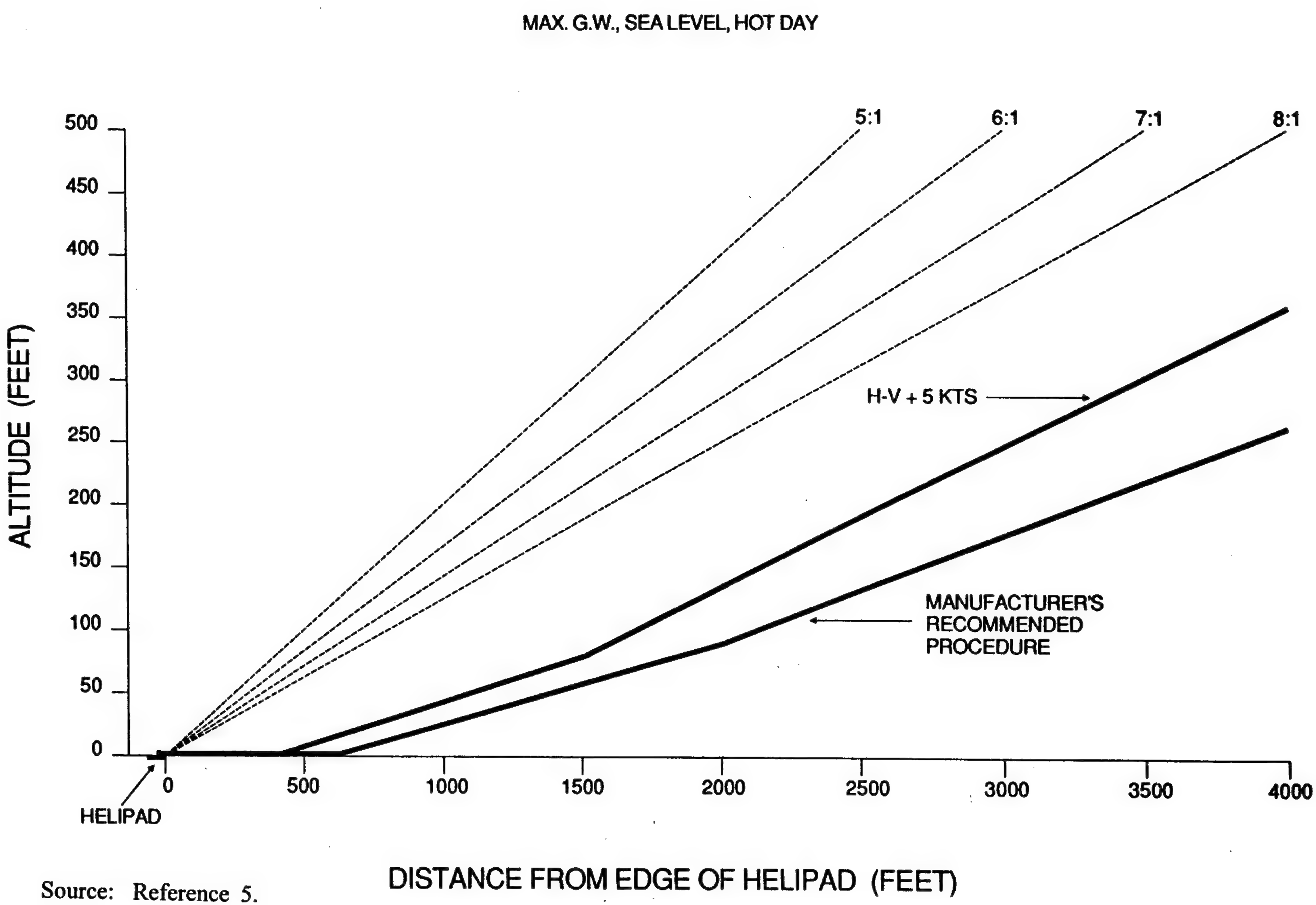
- "Helicopter Physical and Performance Data," DOT/FAA/RD-90/3 (reference 16);
- "Heliport VFR Airspace Design Based on Helicopter Performance," DOT/FAA/RD-90/4 (reference 5);
- "Operational Survey - VFR Heliport Approaches and Departures," DOT/FAA/RD-90-5 (reference 6);
- "Rotorcraft Acceleration and Climb Performance Model," DOT/FAA/RD-90-6 (reference 17); and
- "Helicopter Rejected Takeoff Airspace Requirements," DOT/FAA/RD-90-7 (reference 18).

One conclusion that can be drawn from these studies is that existing heliport design criteria do not adequately account for actual rotorcraft performance characteristics, either in terms of real estate requirements or airspace. (Subsequent to the publication of the 1994 Heliport Design AC, this situation is largely unchanged.)

The reports focused on helicopter departure and climb capabilities, as well as the takeoff performance of various categories of rotorcraft. The results are based largely on data contained in rotorcraft flight manuals as well as a survey of helicopter pilots, and highlight a number of specific areas where rotorcraft performance does not match the FAA's heliport design criteria.

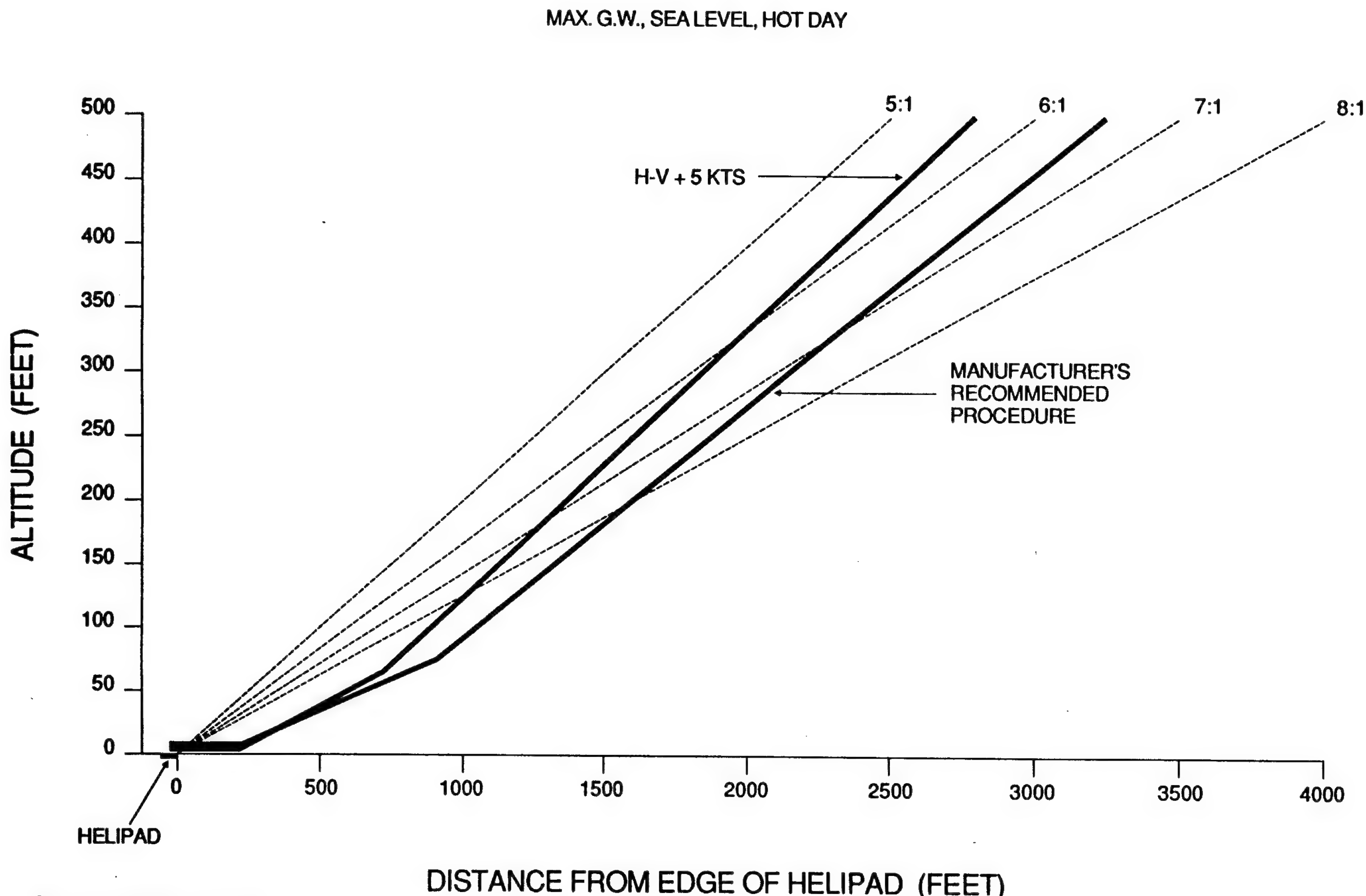
In particular, the studies showed that under certain weight, density altitude, and temperature conditions, a large number of rotorcraft could not climb at an 8:1 slope, as prescribed in the AC. In addition, many helicopters could not perform direct climb maneuvers (simultaneously climbing and accelerating) when operating from TLOFs with no room for horizontal acceleration. PACER Systems was the first to recommend development of a heliport maneuver area (HMA) that allowed sufficient room for horizontal acceleration in ground effect (IGE) to fly through translational lift +5 knots (approximately 25 knots indicated airspeed (IAP)) (see figures 11 through 16). Such an HMA would be at least 400 feet long, and would ensure that most rotorcraft could climb VFR at an angle greater than 8:1 (see figure 17). Based on later research by SAIC (reference 5), the current AC, "Heliport Design," recommends that the FATO be at least 200 feet long, to be increased as the elevation of the FATO increases (figure 18).

Various studies have noted that the data provided to pilots in rotorcraft flight manuals are inadequate when operating to and from confined heliport environments (reference 5), as the quote below highlights:



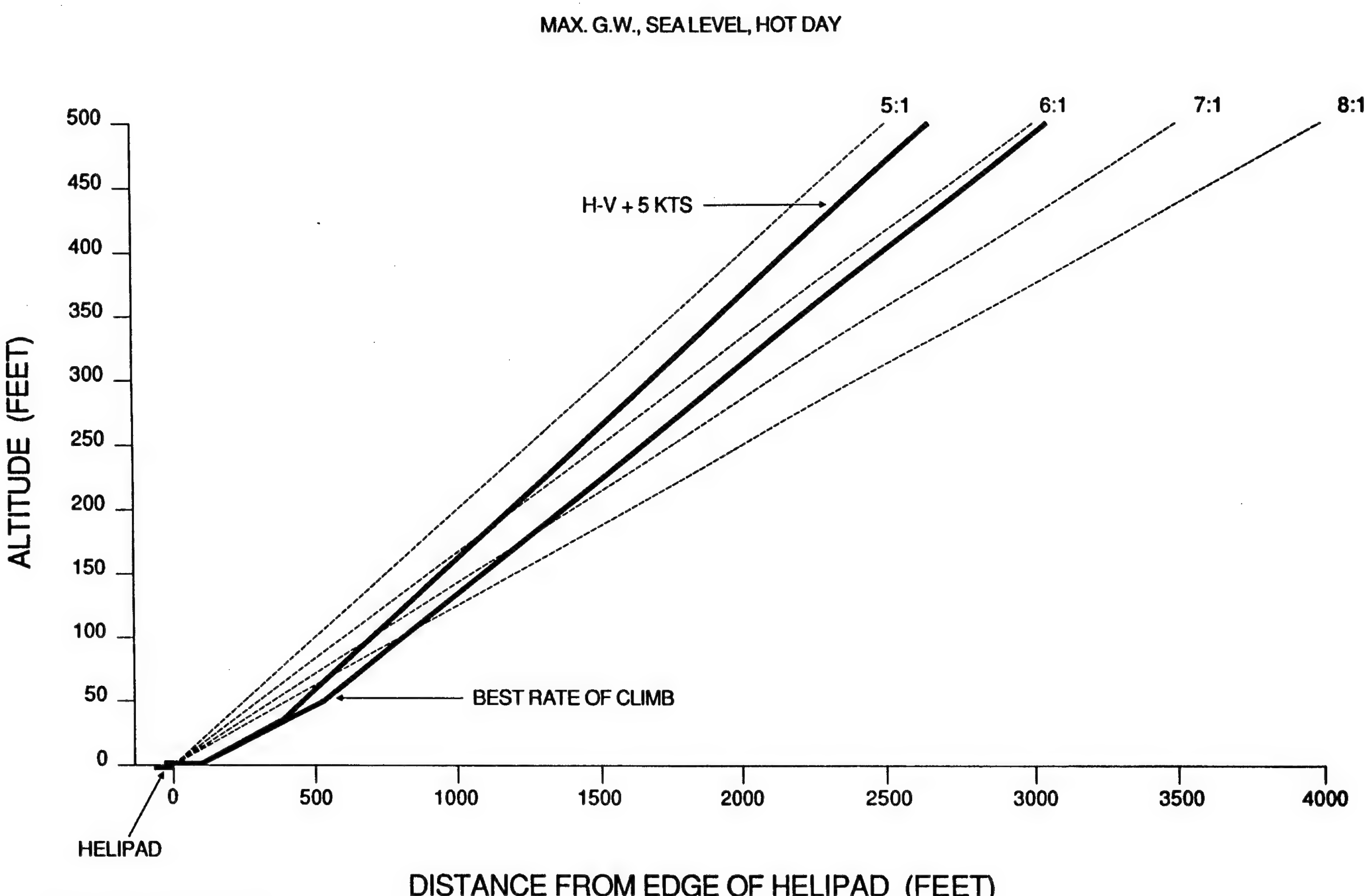
Source: Reference 5.

FIGURE 11 F-28F DEPARTURE PROFILES



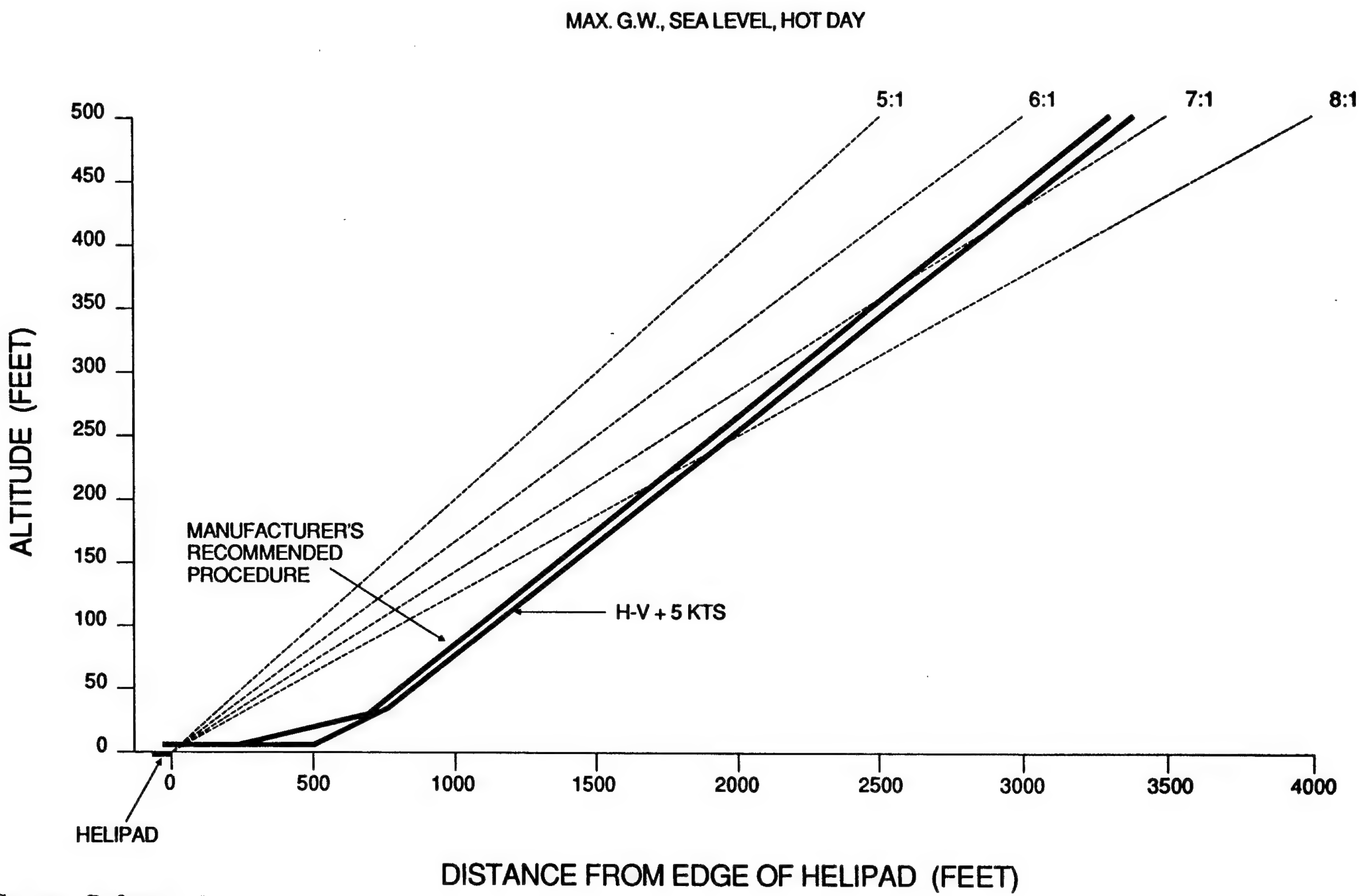
Source: Reference 5.

FIGURE 12 MD 500E DEPARTURE PROFILES



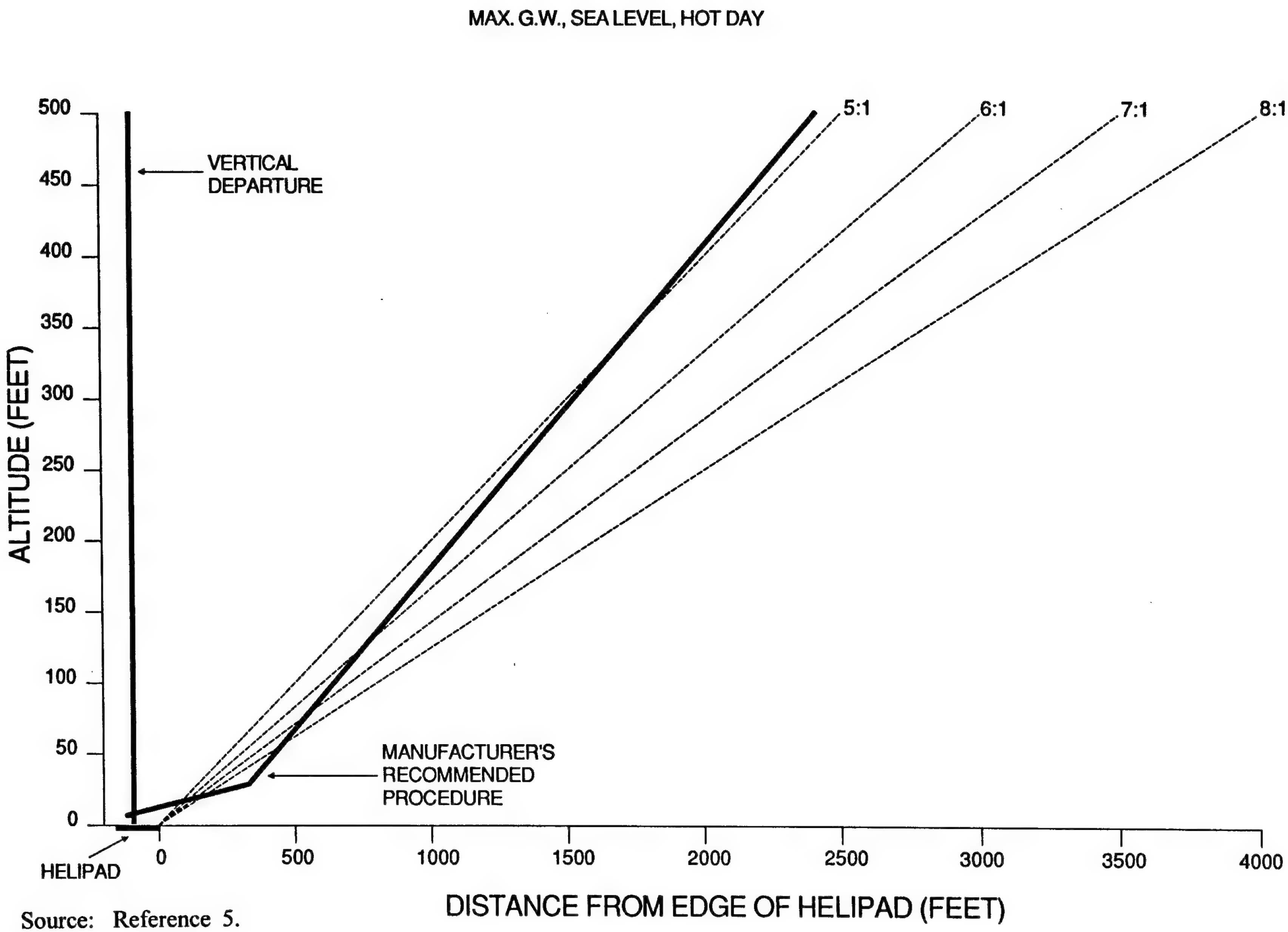
Source: Reference 5.

FIGURE 13 B 206B DEPARTURE PROFILES



Source: Reference 5.

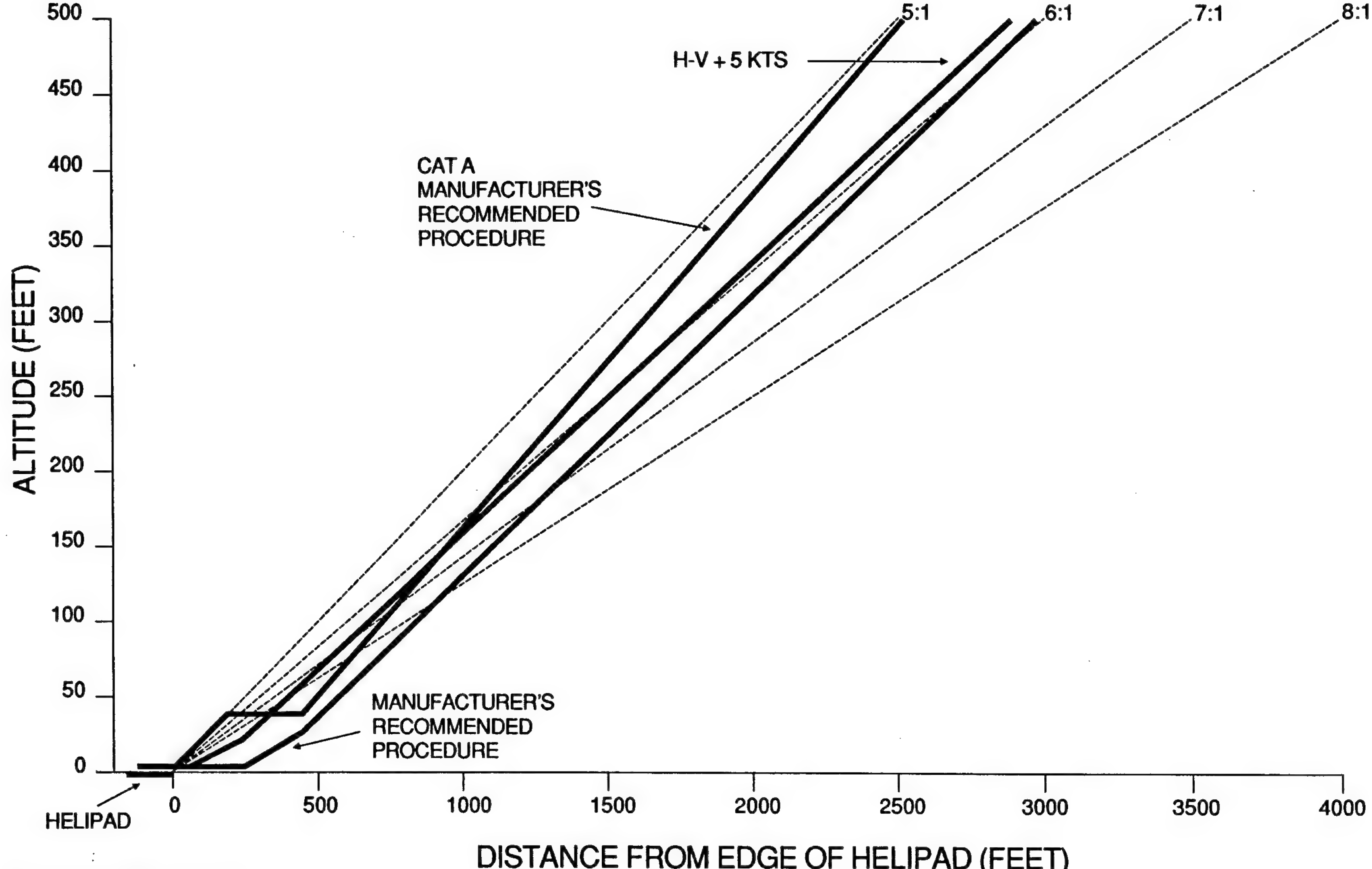
FIGURE 14 MBB BO 105 CBS DEPARTURE PROFILES



Source: Reference 5.

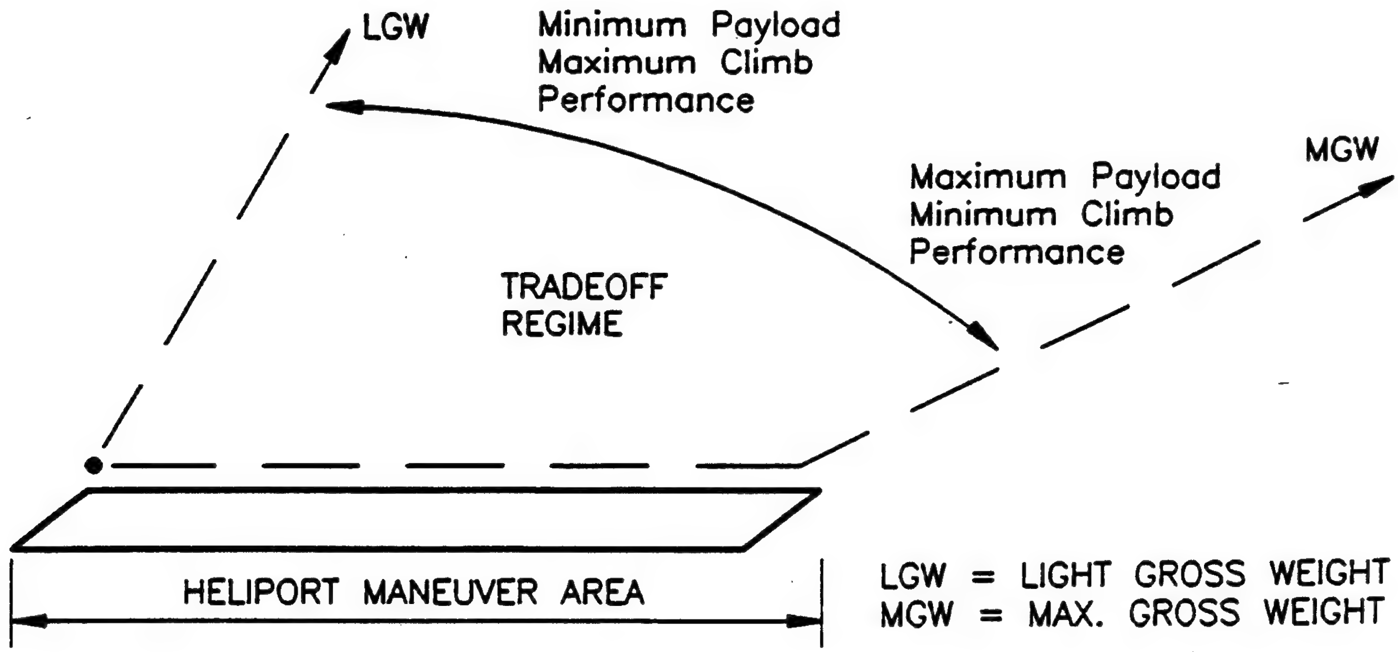
FIGURE 15 AS 355 F DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, HOT DAY

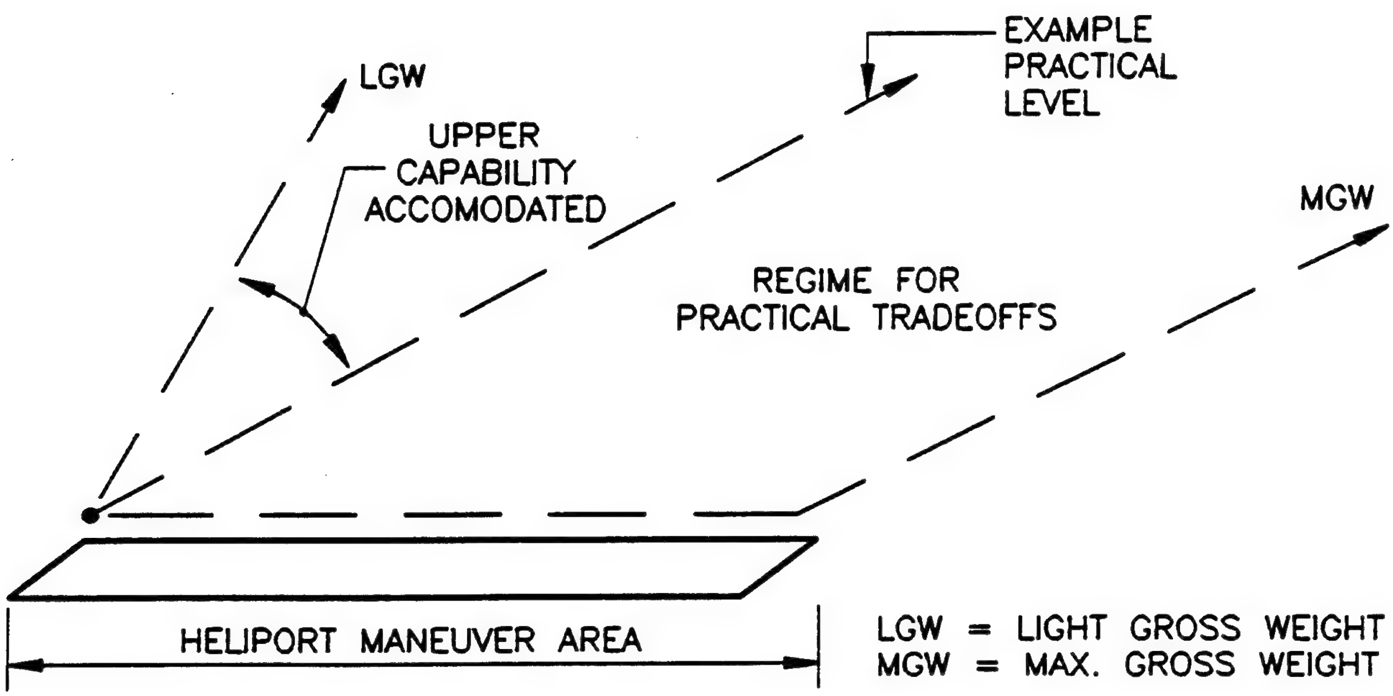


Source: Reference 5.

FIGURE 16 S 76A DEPARTURE PROFILES



HELIPORT TRADEOFF REGIME



PRACTICAL APPLICATION OF TRADEOFFS

Not to scale.

Source: Reference 13.

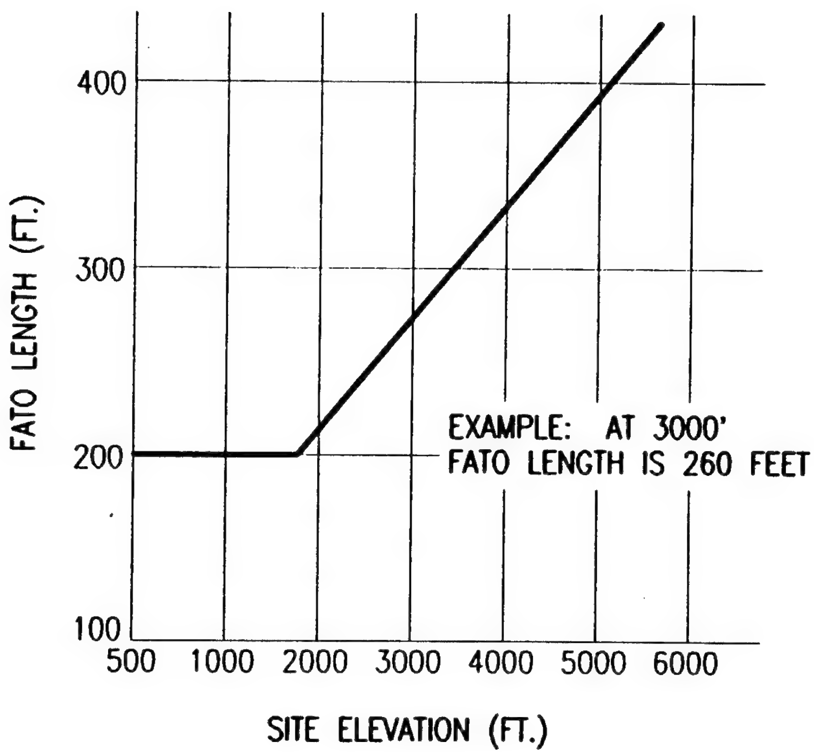
FIGURE 17 HELIPORT REAL ESTATE AND AIRSPACE PLANNING DECISION

COMMERCIAL SERVICE HELIPORT FATO

SIZE
DIMENSIONS ARE PREDICATED ON A RECTANGULAR FATO.

WIDTH
THE WIDTH OF THE FATO FOR PUBLIC USE COMMERCIAL SERVICE HELIPORT IS TWICE THE ROTOR DIAMETER OF THE DESIGN HELICOPTER. THE RECOMMENDED MINIMUM WIDTH OF A PUBLICLY OWNED COMMERCIAL SERVICE HELIPORT IS 100 FEET (30 m).

LENGTH
THE RECOMMENDED LENGTH OF ALL PUBLIC USE COMMERCIAL SERVICE HELIPORT FATOs IS OBTAINED FROM THE FIGURE BELOW.



Source: Reference 1.

FIGURE 18 CURRENT FATO LENGTH RECOMMENDATION

"Both Normal and Transport Category helicopters need several items of performance data in their flight manuals not universally provided, and some items not provided at all. These former items include HIGE [hover in ground effect] and HOGE [hover out of ground effect] performance and rate of climb at V_y for takeoff at maximum continuous power. These data are usually, but not always, provided. ...[Among the information that is not provided at all is] vertical rate of climb and direct climb data, similar to that provided in this report for the generic helicopter performance classifications, and climb data for the best angle of climb which avoids height velocity (HV) limitations. Similar data are needed for OEI operations to the extent to which they apply. All data should be presented in a readily interpreted manner which will enable pilots to compare the capabilities of their aircraft to the requirements posed by particular heliports experiencing particular weather phenomena."

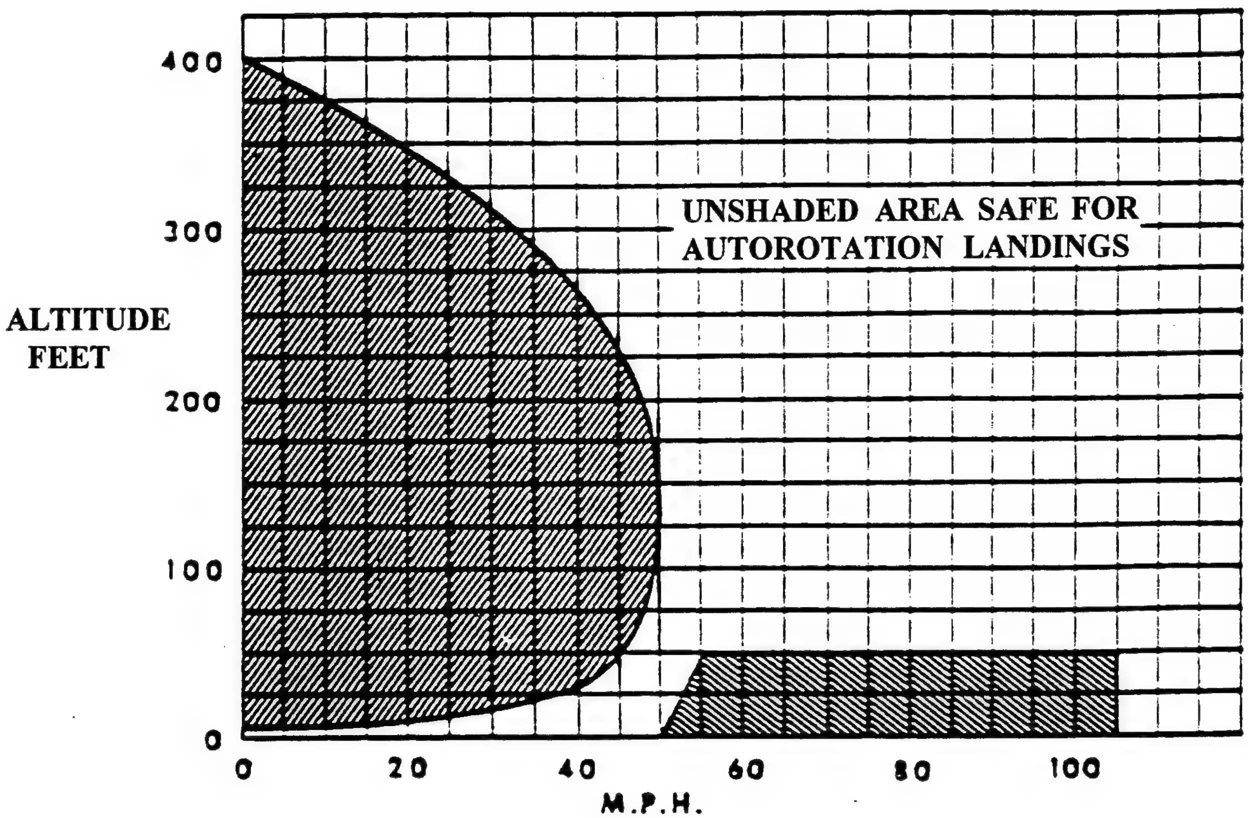
The conclusions provided in FAA's "Safe Heliports Through Design and Planning" (reference 8) drew upon the results of these studies in recommending heliport acceleration (maneuver) areas and larger approach surfaces. The FAA report noted that:

"The FAA has studied this issue [VFR airspace] in a multi-faceted R&D program involving flight testing, analysis of certification data, operational survey of industry helicopter pilots, and helicopter accident analysis. To varying degrees, each facet of this effort indicates a need for an increase in the minimum required VFR heliport airspace."

Further, the "...data from flight testing, subjective pilot surveys, and accident analysis, have all supported the requirement for additional parking and maneuvering space," in the vertical and lateral dimensions in order to increase safety margins. As noted previously, a heliport maneuver area is also necessary for rotorcraft to meet Category A requirements without having to HOGE, which will increase gross takeoff weight and useful load under certain conditions.

2.4.2 Height Velocity (HV) Curves as They Affect Takeoff Performance

Another important factor regarding helicopter performance capabilities is height velocity (HV) curves. HV curves are developed for each helicopter as part of the aircraft certification process, for both normal and transport category rotorcraft. The HV curves designate so-called avoid areas, are expressed as combinations of airspeed and altitude, and denote areas from which a safe autorotation could not be made in the event of an engine failure, as seen in figure 19. HV curves generally require an acceleration within 15 to 20 feet above ground level (AGL) to a speed of 20 to 40 knots before initiating a climb. This would effectively preclude direct climb techniques that require simultaneous acceleration and climb capability.



Airspeed vs. altitude limitations chart.

Courtesy Bell Helicopter Corporation.

Source: Basic Helicopter Handbook, ACG1-13B, FAA.

FIGURE 19 TYPICAL HEIGHT/VELOCITY CURVE FOR
A SINGLE-ENGINE HELICOPTER

In order to operate safely within the area of the HV curve, many helicopters need horizontal acceleration areas, as recommended by PACER Systems (reference 13) and SAIC (reference 5). However, most existing heliports, particularly those with minimum sized FATOs, do not have accelerations areas. As a result there is not adequate space for rotorcraft to comply with their HV curve and they consequently fly within the recommended avoid areas. Therefore, the HV curve directly influence design requirements for large heliports/vertiports.The report, "Heliport VFR Airspace Design Based on Helicopter Performance" (reference 5), recommends using a technique called HV+5, in which the departure profile includes acceleration in ground effect until passing through translational lift (assumed to be 20 knots), then an accelerating climb (at 1 foot of altitude per 1 knot of indicated airspeed (IAS)) until reaching the knee of the avoid curve +5 knots or V_y. This procedure, also requires an HMA. The acceleration distance required is expressed by the formula:

$$HADR = 140 + (25)(FE/1,000) + (5)(FE/1000)^2,$$

where,

HADR = Heliport acceleration distance required, in feet
FE = Field elevation in feet above sea level.

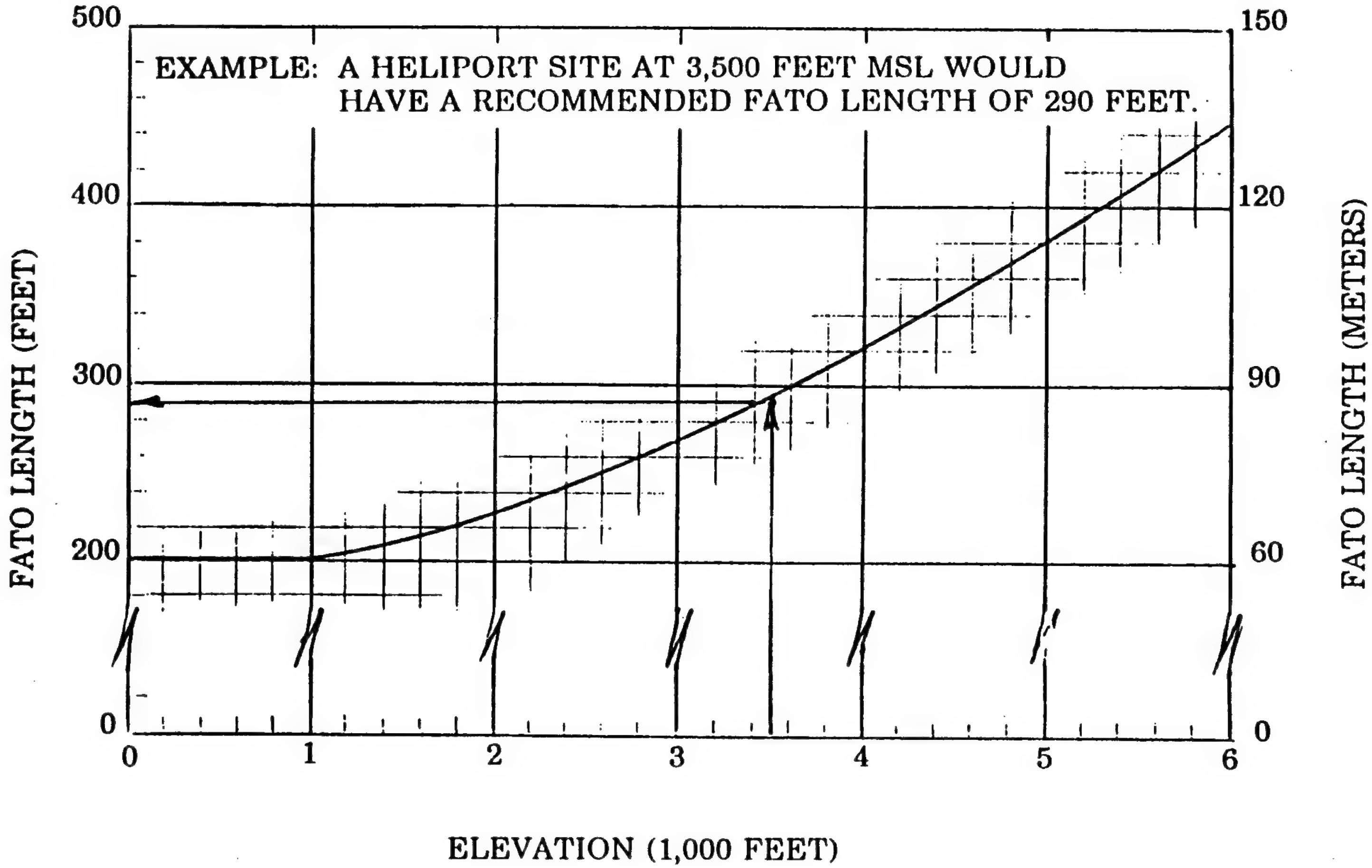
The graph shown in figure 20, which is from the heliport design AC (reference 1), was developed based on this formula.

2.5 CTR PERFORMANCE CAPABILITIES AND CERTIFICATION

Two programs initiated FAA's certification process for new vertical flight aircraft at approximately the same time, Bell-Boeing with the CTR and the Ishida Group's TW-68 tiltwing aircraft (the tilt-wing program has since been cancelled). Primarily in response to those programs, as well as others discussed in the 1980s and 90s such as Magnum Aircraft's normal category tiltrotor, the FAA determined that existing aircraft and rotorcraft certification standards did not apply to the new technology VTOL aircraft. The FAA then established a new interim powered-lift transport aircraft regulation for their certification.

All such VTOL programs are classified by the FAA as powered-lift aircraft and will be covered under the new interim criteria. The certification criteria will apply to tiltrotors, tiltwing, fan-in-wing, and vectored thrust aircraft. No aircraft has received a type certificate under the new regulation (see section 1.1), so there is no experience with actual aircraft performance characteristics or limitations.

Aircraft certification is important because the FAA determines the allowable performance envelope based on those standards, which include takeoff and landing distances, flight into known icing, minimum and maximum approach and climb speeds, gross weight, useful load and payload, height-velocity curves, etc. As noted previously, conventional rotorcraft are limited by certification criteria from executing steep and slow approaches under IMC conditions, as well as being prohibited from flight into known icing. In fact, the FAA did not certify the first civilian helicopter for IFR operation until the mid 1970s. It is widely held that CTR aircraft cannot operate under these same helicopter restrictions and provide a level of service that is competitive with fixed-wing air carriers.



Source: Reference 1.

FIGURE 20 FATO LENGTH

In order to provide the level of service projected by Bell-Boeing and NASA in their two CTR missions and applications studies (references 7 and 19), the tiltrotor must be certified by the FAA to operate:

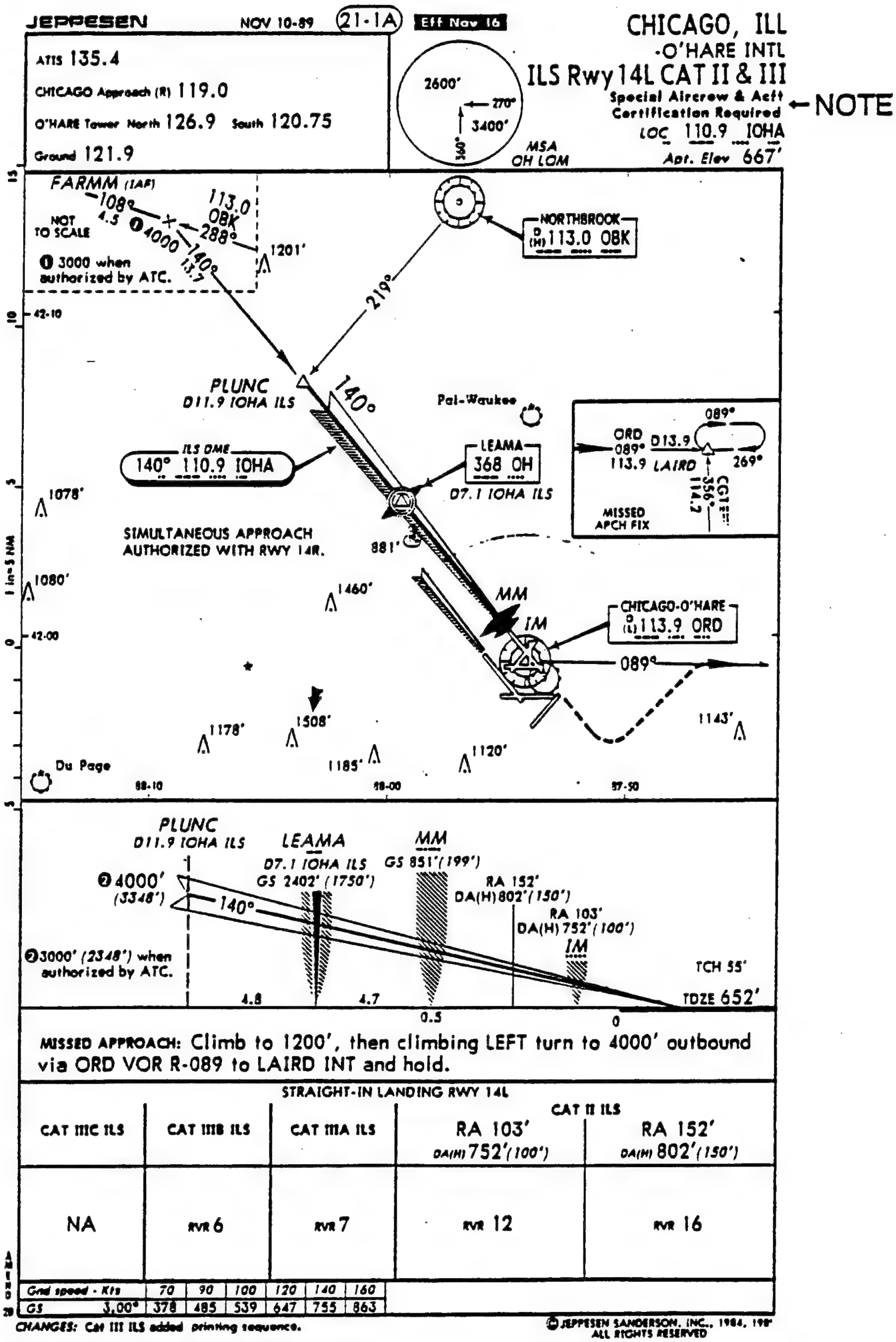
- VFR and IFR, day and night, with no restrictions;
- into known icing, similar to existing transport category aircraft;
- on steep and slow instrument approaches to Category I, II, and III minimums;
- with full Category A OEI capability; and
- in both the VTOL and STOL modes.

One of the basic criteria in aircraft certification is the determination by the FAA that aircraft performance can be achieved by pilots with average skill and experience levels, that no extra-ordinary skills are required to operate the aircraft. Therefore, procedures that may be within the aircraft's capabilities, such as slow and steep approaches, may not be allowed by the FAA if they determine that to perform such maneuvers requires above-average pilot skill and experience. The FAA has already established precedence for certifying procedures (e.g., instrument landing system (ILS) Category II and III instrument approaches) that require higher than standard pilot training and experience levels. Regulation 14 CFR 91, General Operating Rules, specifies minimum training and experience levels necessary to execute ILS Category II and III approaches, and such restrictions are also stated on each instrument approach plate (see figure 21). Similar special requirements could be instituted for particular CTR procedures that private pilots would not be expected to perform.

At this time, the FAA has not yet certified any aircraft to perform such steep and slow (less than 60 knots indicated) approaches. A key element of the certification process will be to document that such procedures can be safely and consistently performed by average pilots. Alternatively, pilots will be required to meet specific training and experience levels to execute steep/slow approaches, as they are now for ILS Category 2 and 3 approaches.

The NASA Phase II report (reference 19) concluded that 12 to 15-degree approaches were preferred based on the results of V-22 simulator (modified for the CTR-22) flight tests.

Using approach speeds between 30 and 38 knots and an 800 foot per minute rate of descent resulted in the best pilot visibility, passenger comfort, reduced ground distance, and adequate flight safety, according to Bell-Boeing. However, in this research, failure modes and required minimum equipment were not addressed. The pilot workload increases significantly if aircraft avionics are not functioning 100 percent. More recent flight test



NOTE: NOT TO BE USED FOR NAVIGATION.
USED WITH THE PERMISSION OF JEPPESEN SANDERSON, INC.

FIGURE 21 APPROACH PLATE WITH RESTRICTIONS

data from NASA and industry simulators suggest that 9-degrees may be the optimum approach angle. Although more testing is required before a final decision can be made on this issue, the "segmented 9-degree" approach appears to be the best alternative at this time. A "segmented 9-degree" approach is also attractive from an environmental perspective because it has a small noise footprint.

Part of the answer concerning how to perform instrument approaches will be based on what type of navigation aid will be available when the CTR is certified. It is expected that dGPS will become the optimum precision approach aid for CTR aircraft, partly due to its accuracy and flexibility. Assuming that dGPS does become the primary instrument navigation aid, precision approaches of any angle might be possible and would only be limited by the aircraft performance.

Another performance characteristic that will be studied during certification is takeoff and landing distance requirements. The NASA Phase I study (reference 7) noted that the CTR-22C could increase its range and payload significantly with a 750 foot "runway," compared to vertical takeoff procedures. The impact of a 750 foot acceleration area on CTR performance is based on Bell-Boeing's estimate of its capabilities; however, no more specific information is available.

Until advanced aircraft, such as the CTR, is actually certified under the powered-lift aircraft regulation and receives a type certificate from the FAA, there is no conclusive definition of what operating capabilities will be allowed.

Both the NASA study (reference 7) and the FAA Vertiport Design AC (reference 2) looked at FATO design requirements from an economic perspective, i.e., longer FATO's would allow greater range and payload. However, the CTRDAC took a different approach on the issue of FATO length. Rather than the economic perspective, the CTRDAC took a safety, i.e., how long does the FATO need to be in order to operate safely in the event of a single-engine failure. Since aviation safety must take priority over economics, this is the perspective that must be taken in future analysis of vertiport FATO design requirements.

2.6 FEDERAL AVIATION REGULATIONS

Many Fads apply primarily to airports because they are applicable to facilities that provide scheduled passenger service. However, as large heliports and vertiports attract scheduled service by certificated VTOL carriers, many of the Fads that apply to airports will also apply to heliports and vertiports. This description of various Fads focuses on the impact of the regulations on facility design issues. Several regulations can be expected to have a significant impact on vertiport design and operating criteria.

2.6.1 14 CFR 77 - Objects Affecting Navigable Airspace

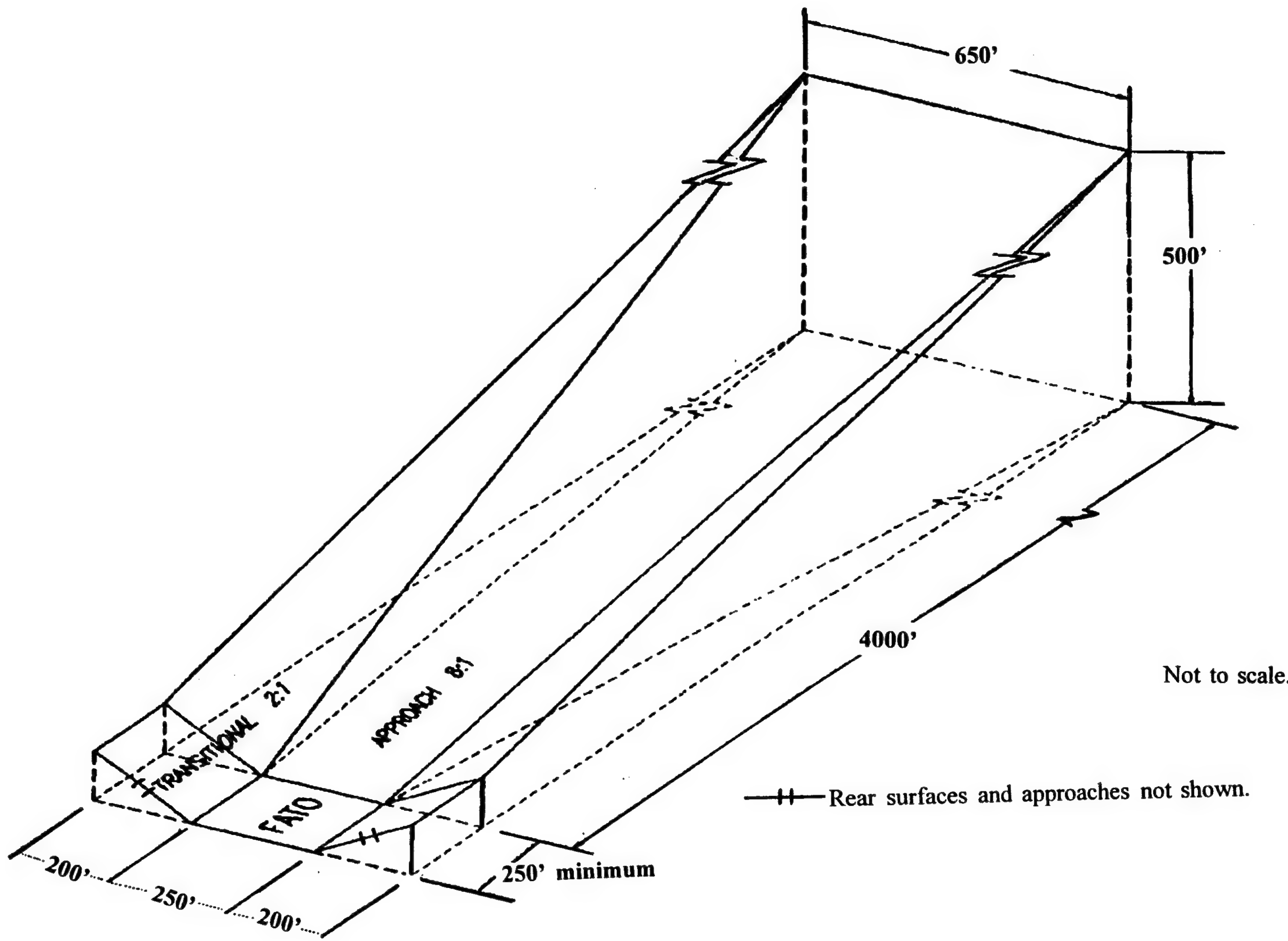
14 CFR 77, "Objects Affecting Navigable Airspace," prescribes airspace limits surrounding airports and heliports that establish a standard for determining obstructions to air navigation. Objects that penetrate those surfaces are classified as obstructions and require an aeronautical study to identify the actual effect on navigable airspace.

Both the heliport and vertiport design ACs specifically reference 14 CFR 77; however, the regulation itself does not have any reference to vertiports. The 14 CFR 77 imaginary surfaces prescribed for heliports are for visual approaches only, unlike the criteria for airports which categorize runways by types of approaches (visual, nonprecision instrument, and precision instrument) and visibility minimums. Instrument approach procedures (IAP), including imaginary surfaces, are described in both the heliport and vertiport design ACs; however, these criteria are not reflected in 14 CFR 77. 14 CFR 77 does provide general criteria for determining which objects located on or in the vicinity of a heliport are obstructions and a process for determining their potential hazard to air navigation. Figure 22 shows the applicable VFR vertiport imaginary surfaces.

One of the limitations of 14 CFR 77 is that it does not give the FAA the authority to either remove an existing structure or to prevent the construction of new obstructions. The FAA does require recipients of Federal grants to sign assurances that they will gain control of adjacent property to prevent penetrations of imaginary surfaces adjacent to heliport/vertiport property. However, if the sponsor does not have the financial or legal capability of acquiring either the property or the easements under the approach or transitional surfaces, particularly at heliports located in urban areas, the imaginary surfaces cannot be protected from penetrations and the FAA grant assurance will not be met. Lack of protection of imaginary surfaces may also preclude the FAA from installing or certifying an instrument approach to a heliport or vertiport based on obstacle encroachment.

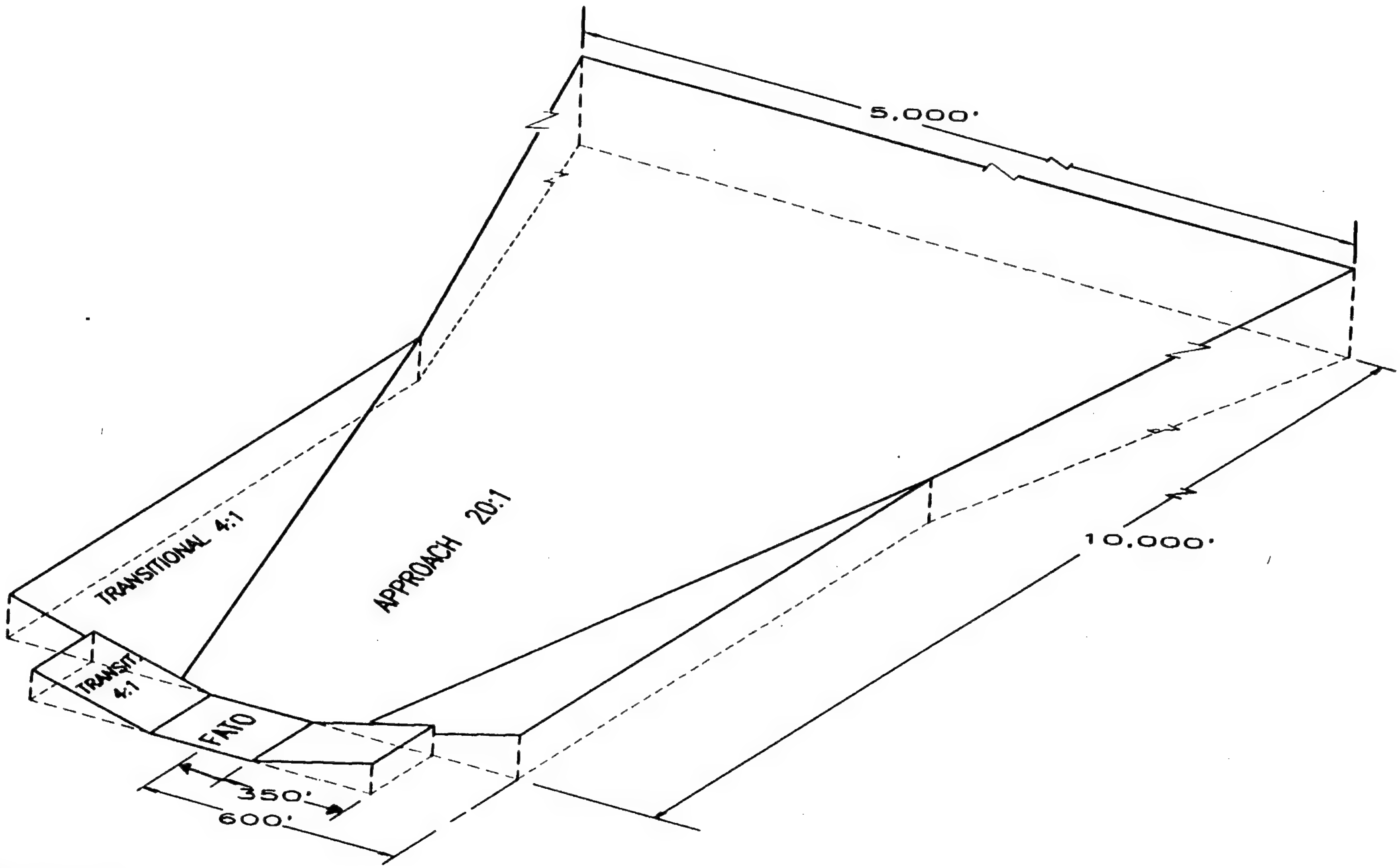
Although the heliport and vertiport instrument approach imaginary surfaces are not shown in 14 CFR 77, the imaginary surfaces presented in the ACs (references 1 and 2) would become mandatory if a sponsor accepted Federal grants and installed an instrument procedure. Heliport and vertiport imaginary surfaces applicable to non-precision and precision instrument approaches are shown in figures 23 through 26. (It should be noted that these imaginary terminal instrument procedures (TERPS) surfaces were developed under the assumption that terminal navigation would be provided by MLS. However, it is now clear that GPS will be used instead of MLS. GPS non-precision TERPS have been developed and will be finalized and published in 1996. GPS Category 1 precision approach TERPS data collection is scheduled to start in the summer of 1996. As a consequence, both the non-precision and precision TERPS surfaces in figures 23 through 26 can be expected to change.)

This lack of protection of imaginary surfaces will be further exacerbated by the application of precision instrument procedures for heliports and vertiports. According to both design ACs, the precision instrument heliport/vertiport approach surfaces, based on a 6-degree glideslope, extend outward for a distance of 25,000 feet from the edge of the FATO to a width of 9,000 feet, as shown in figure 25. Vertiports with a 9-degree approach slope, which simulation tests support as the preferred angle, decrease that distance to 10,000 feet and a width of 7,000 feet. Yet either of these areas are notably larger than the rudimentary visual surface defined in 14 CFR 77. Currently, the FAA has not certified a precision instrument approach to any public-use heliport or vertiport in the United States.



Source: Reference 2.

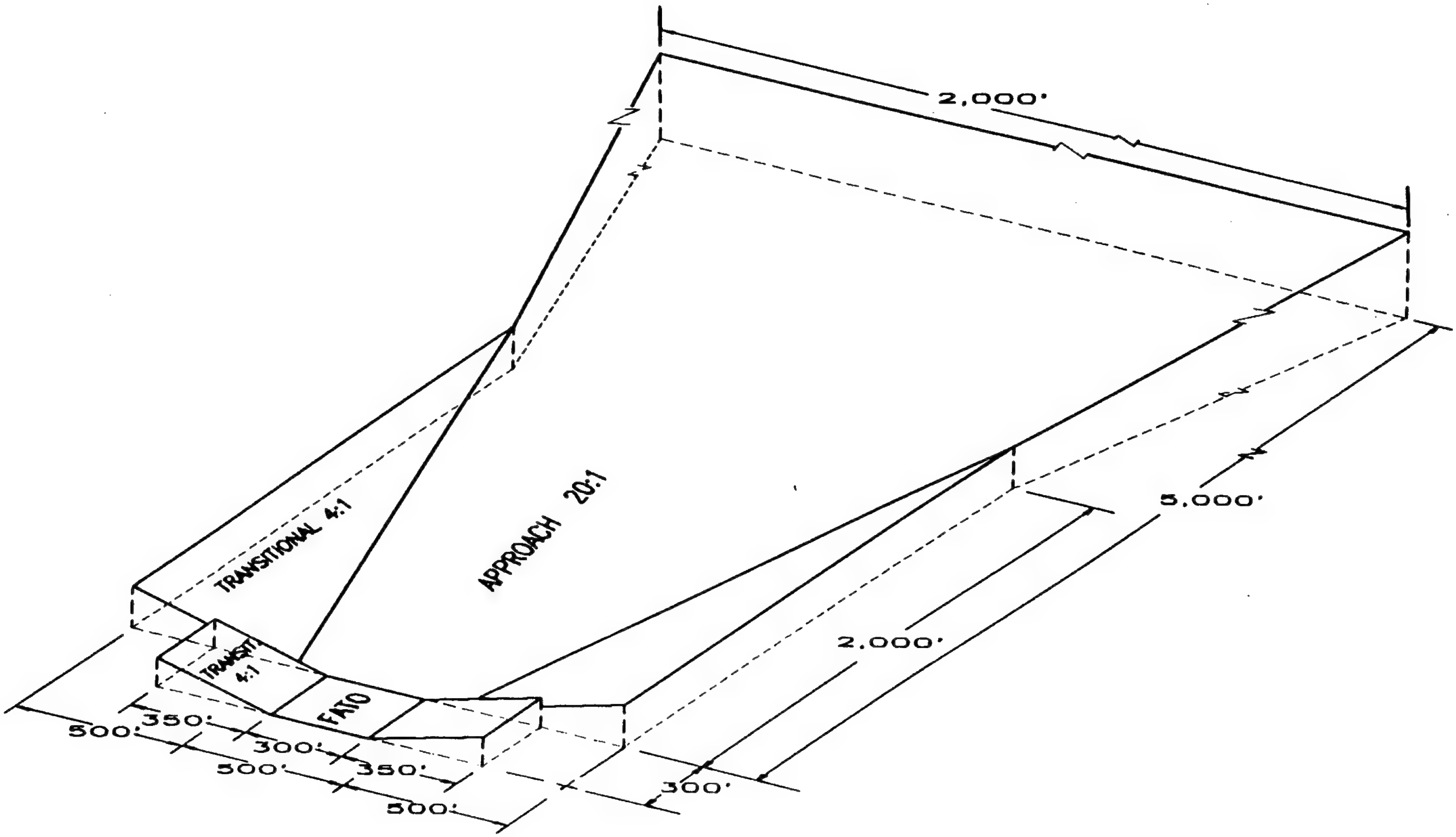
FIGURE 22 VFR VERTIPORT IMAGINARY SURFACES



Not to scale.

Source: Reference 1.

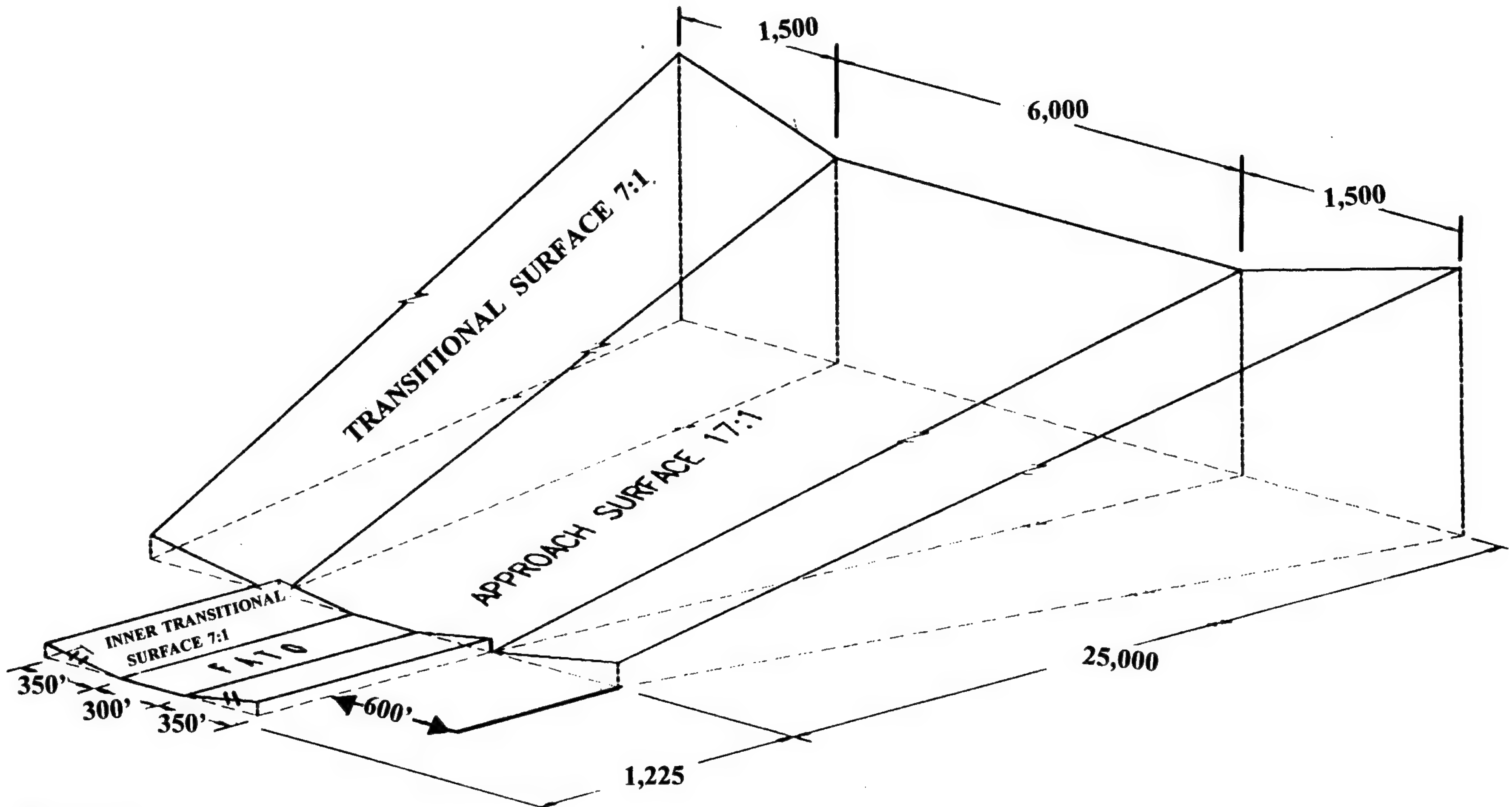
FIGURE 23 HELIPORT NONPRECISION INSTRUMENT APPROACH SURFACES



Not to scale.

Source: Reference 2.

FIGURE 24 VERTIPORT NONPRECISION INSTRUMENT APPROACH SURFACES

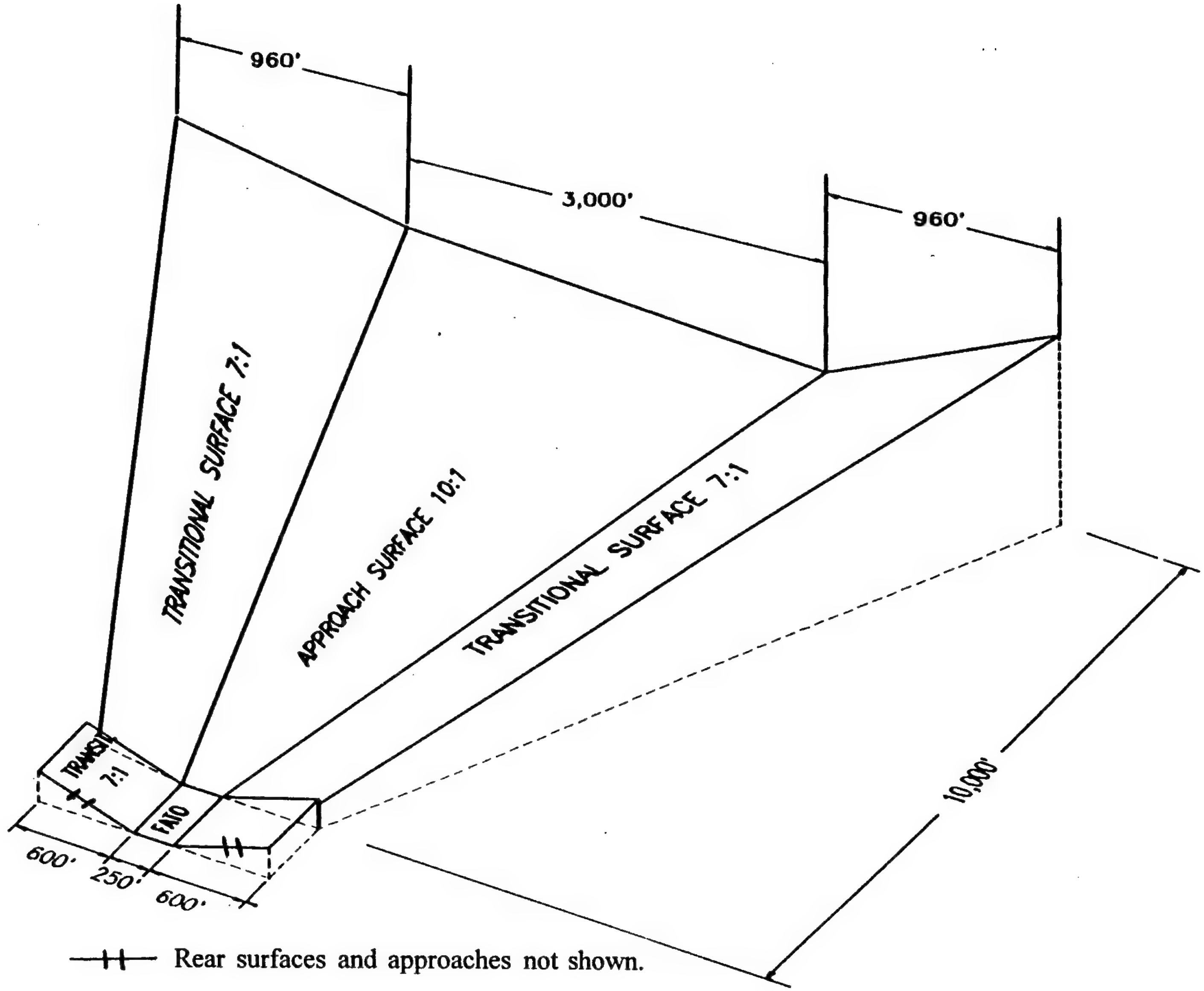


Not to scale.

Source: Reference 1 and 2.

Rear surfaces and approaches not shown.

FIGURE 25 LARGE HELIPORT/VERTIPORT 6-DEGREE PRECISION INSTRUMENT APPROACH SURFACES



Not to scale.

Rear surfaces and approaches not shown.

Source: Reference 2.

FIGURE 26 VERTIPORT 9-DEGREE PRECISION INSTRUMENT APPROACH SURFACES

2.6.2 14 CFR 97 and Terminal Instrument Approach Procedures (TERPS)

The "U.S. Standard for Terminal Instrument Procedures (TERPS)," FAA Order 8260.3B (reference 20), prescribes the standards and procedures for developing instrument approach IAPs to airports and heliports. Once IAPs have been implemented and approved by the FAA based on TERPS, they are incorporated into and specifically referenced in 14 CFR 97, Standard Instrument Approach Procedures. 14 CFR 97 describes all FAA approved IAPs which serve as the basis for development of instrument approach charts used by pilots.

FAA Order 8260.3B, Chapter 11, "Helicopter Procedures" (reference 20) prescribes the instrument approach criteria for helicopter-only procedures. As noted in the first paragraph:

> These criteria are based on the premise that helicopters are approach Category A aircraft with special maneuvering characteristics. The intent, therefore, is to provide relief from those portions of other TERPS chapters which are more restrictive than the criteria specified herein. However, any criteria contained elsewhere in other chapters of this document may be applied to helicopter-only procedures when an operational advantage may be gained. Criteria contained elsewhere in this document normally apply to helicopter procedures. Where this chapter changes such criteria, the changed material is identified.

No reference is made in the TERPS order to vertiports, nor has any instrument approach criteria been issued for CTRs at this time. A recent report prepared by Systems Control Technology, Inc., "Heliport/Vertiport MLS Precision Approaches" (reference 21), provides a detailed analysis of the impact of meeting TERPS requirements for a precision MLS approach. The report concludes that installation of a precision approach would increase both the real estate and airspace requirements for a heliport, which is consistent with the conclusions drawn by the VFPO in their report, "Safe Heliports Through Design/Planning," (reference 8) (also see section 1.2).

One nonprecision instrument approach procedure has been developed specifically for helicopters; a point-in-space approach. The procedure is designed for locations where the landing site is more than 2,600 feet from the missed approach point (MAP), and helicopters proceed under visual conditions from the MAP to the heliport. The imaginary surfaces at a heliport with a point-in-space approach are visual surfaces, similar to circle-to-land requirements at an airport. The visibility minimums for a point-in-space approach can be as low as 3/4 mile; however, they are typically 500 feet and 1 mile or greater.

It is apparent that helicopter instrument approach criteria, with the exception of the point-in-space approach, are adaptations of fixed-wing standards. TERPS does allow steeper approach angles on precision approaches than fixed-wing aircraft; however, (glideslope) angles greater than 6-degrees will not be established without authorization of the approving authority. The angle selected should be no greater than that required to provide obstacle clearance and to provide the lowest minimums. With a glideslope angle of

less than 3.8-degrees, a decision height (DH) of 100 feet could be achieved, increasing to a 200 foot DH with a glideslope angle greater than 5.7-degrees. However, since no precision approaches have been certified to heliports, there is no civilian operational experience to draw upon except simulator and flight test data.

It should be noted that IFR certified helicopters do use existing ILS approaches at airports, typically with a 3-degree glideslope and DH of 200 feet and 1/2 mile visibility. Their approach speeds, based on rotorcraft flight manuals, are similar to piston engine fixed-wing aircraft, ranging between 60 to 120 knots. Fixed-wing aircraft are classified as approach Category A if their approach speed is no greater than 90 knots, while all helicopters are classified in TERPS as approach Category A, regardless of approach speed.

TERPS does not stipulate approach speeds that rotorcraft must use to achieve a minimum DH, although as Category A aircraft it is assumed that they approach at 90 knots or less. It should be noted that the regulations allow straight-in approaches to be flown at any airspeed, and the approach category will not technically change since it is a calculated number, not at an actual performance limit. It is recommended that if approaches are flown at higher speeds, the appropriate higher approach category minimums should be used. Circle-to-land approaches, on the other hand, require the actual approach speed to be maintained within the limits of the appropriate category.

In addition, TERPS does not address any need for increased real estate requirements for FATOs or TLOFs to accommodate IFR rotorcraft operations. It is the pilot's responsibility to determine if the rotorcraft has the performance capability to meet the published departure and approach procedures to the facility. As noted by various FAA R&D reports, additional real estate is required for IFR rotorcraft departures in order to allow rotorcraft to accelerate to V_y prior to initiating their climb in IMC. In addition, rotorcraft must maintain a minimum approach speed until they are in VMC, which requires a heliport deceleration area. By their airworthiness certificates, civilian rotorcraft are not allowed to perform slow flight (less than 60 knots indicated) or hovers in IMC.

2.6.3 14 CFR 139, Certification and Operation: Airports Serving CAB Certificated Air Carrier Aircraft and 14 CFR 107, Airport Security

The two regulations, 14 CFR 139 and 107, apply to commercial service airports that accommodate scheduled air carrier service with airplanes of 30 passenger seats or greater. There are no large heliports that fall within the requirements of either regulation; however, it is anticipated that the advent of scheduled service by the CTR-22C and possibly by large helicopters such as the EH-101 and S-92 would require compliance with both 14 CFR 139 and 107. Appendix B provides a detailed analysis of the impact of complying with those regulations on vertiport and large heliport design and operation. Facilities such as aircraft rescue and firefighting (ARFF) buildings will be required, as well as appropriate ARFF equipment and airfield security. In addition, a minimum level of staffing will be required with specific training and record keeping procedures that must be followed and

documented. 14 CFR 139 significantly increases the cost of operating a facility, in addition to the cost of providing the equipment and buildings needed. It is possible that 14 CFR 139 will be revised in response to comments from various groups such as the Airline Pilots Association (ALPA). Changes that may be made are described in the following paragraphs:

- Decreasing the existing threshold of applicability from service by aircraft with 30 passengers or more to smaller airplanes. For example, any airport with scheduled (or non-scheduled) service by a certificated carrier with a 19-passenger seat aircraft or larger would have to be certified under 14 CFR 139 and 107.

- The elimination of limited operating certificates for those airports that receive only non-scheduled service by air carriers. In the future, such airports may have to meet the requirements of a full certificate holder.

- Increasing ARFF requirements at smaller airports. At present, the amount of firefighting capability required at an airport is based on the size of the largest aircraft using the airport (referred to in 14 CFR 139 as Index A and Index B airports). Proposed changes would eliminate many of the differences, and require greater amounts of ARFF capability at smaller airports.

These changes have not been implemented. However, they reflect some of the proposals being considered by the FAA. Changes, if they occur, will likely increase the requirements and therefore the cost to obtain and keep an airport operating certificate.

3.0 IDENTIFICATION OF SPECIFIC SITES

This study identifies general design requirements for vertiports/large heliports by examining the application of the design requirements discussed in the previous sections at five actual sites in the United States. This section provides a description of the sites selected. The subsequent sections discuss aircraft operating characteristics, vertiport/large heliport requirements, and the ability to apply vertiport/large heliport design criteria at each of the selected sites.

3.1 SITES SELECTED

The categories and locations of the selected sites are as follows:

- City Center - Ground Level: Cincinnati, Ohio, Union Terminal
- City Center - Elevated: Phoenix, Arizona, Greyhound Terminal Garage
- Metro Station - Intermodal: Washington, D.C., Union Station
- Suburban - Ground Level: Mansfield, Texas, a suburb of Dallas-Ft. Worth
- Vertiport on Airport: New York, NY, JFK International Airport

These specific sites were chosen several years ago in a time period when the rotorcraft community was focusing on the possibility of 4 to 5 acre vertiports in downtown, urban, "obstacle rich" environments. Since that time, much as occurred to change this line of thinking. Both environmental and capacity issues point to the requirement for significantly larger facilities.

It should be noted that several of these sites would be poor choices for public-use vertiports or large heliports. Generally this is because the land available is simply too small for public-use facilities (although these sites might be adequate for private-use facilities). Consequently, several of these sites collectively illustrate the types of difficulties and limitations that would be encountered at inadequate landing sites. However, since failure is often more instructive than success, even the poor sites have been include for educational purposes.

Four of the five sites selected for analysis purposes were studied as a potential site for a heliport or vertiport in a previous study. Please note that this study does not propose or advocate locating a vertiport or heliport at any of these sites. The sites were selected merely to represent the envelope of general site characteristics that could be encountered in applying design criteria for vertiports/large heliports that support passenger transportation.

3.1.1 City Center, Ground Level - Union Terminal, Cincinnati, Ohio

The Cincinnati Union Terminal in northwest Cincinnati, Ohio has been discussed as a possible site for a heliport since the early 1980s. The Union Terminal site was also included as a possible helistop site in the 1993 draft report "Downtown Heliport/Helistop Feasibility Study" (reference 22) prepared for the City of Cincinnati.

The site is located in the northeastern corner of the Union Terminal parking lot, shown in figure 27. The site is at ground level and measures approximately 150 feet wide by 950 feet long. Electricity, sewer, and potable water are available, as are suitable parking and access. It has been said that the Union Terminal building was "once the most magnificent passenger train station in America" (reference 23). Union Terminal is considered one of the most celebrated art-deco developments in the country. Consequently, this site is sensitive to any kind of development. The structure now houses the Cincinnati Museum of Natural History, the Cincinnati Historical Society, and Omnimax® theater. An Amtrak railroad station is located at the back of the Union Terminal building. The area is bordered on the south by auto parking, on the east by light industrial and commercial building, and on the north by an interstate highway.

The "Downtown Heliport/Helistop Feasibility Study" (reference 22) contains a matrix used to compare 10 potential helistop sites in downtown Cincinnati. It shows that in the feasibility study the Union Terminal site ranked good, on a scale of good, fair, and poor, in terms of arrival/departure routes, adjacent land use, site preparation, and construction cost, and low in terms of proximity (walking distance) and space constraints. The report stated that final selection of a helistop site can only be determined when there is operational demand and proven financial feasibility.

3.1.2 City Center, Elevated - Greyhound Parking Garage, Phoenix, Arizona

The Greyhound bus terminal and garage was proposed as the site for a heliport in the "Phoenix Heliport Needs Study" (reference 24), prepared for the City of Phoenix Aviation Department in 1986. The site is located across the street from the Phoenix Civic Center and a few blocks from the Phoenix Convention Center (see figure 28). The study proposed that a heliport could initially be constructed on top of the existing structure and the city would then acquire the Greyhound property, remove the bus facilities, construct a parking garage, and relocate the heliport to the top deck of the auto parking structure. The existing roof of the Greyhound garage measures approximately 150 feet by 180 feet. Required utilities are available. The Greyhound facilities are in an area zoned "General Commercial and Light Industrial." If the Greyhound terminal was removed and the parking garage expanded, the top floor would provide an area approximately 280 feet by 320 feet for a vertiport.

3.1.3 Metro Station - Union Station, Washington, D.C.

The Union Station is situated a few blocks from the U.S. Capitol building, adjacent to the main business district. The Union Station building is a historic landmark that has been completely renovated and houses both commercial businesses as well as a working railroad terminal. It also has a metro station, bus and taxi service, and large automobile parking capacity.

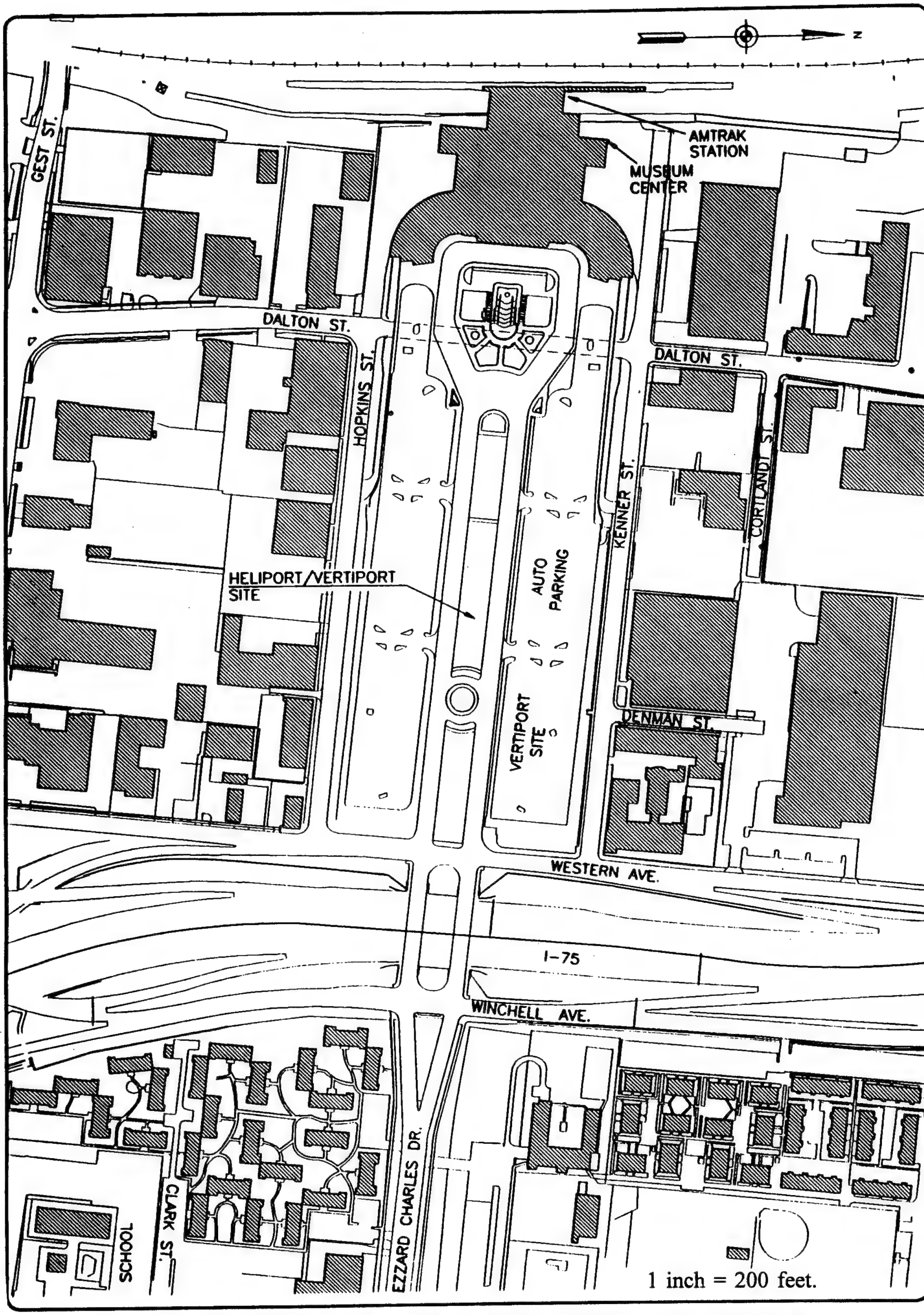
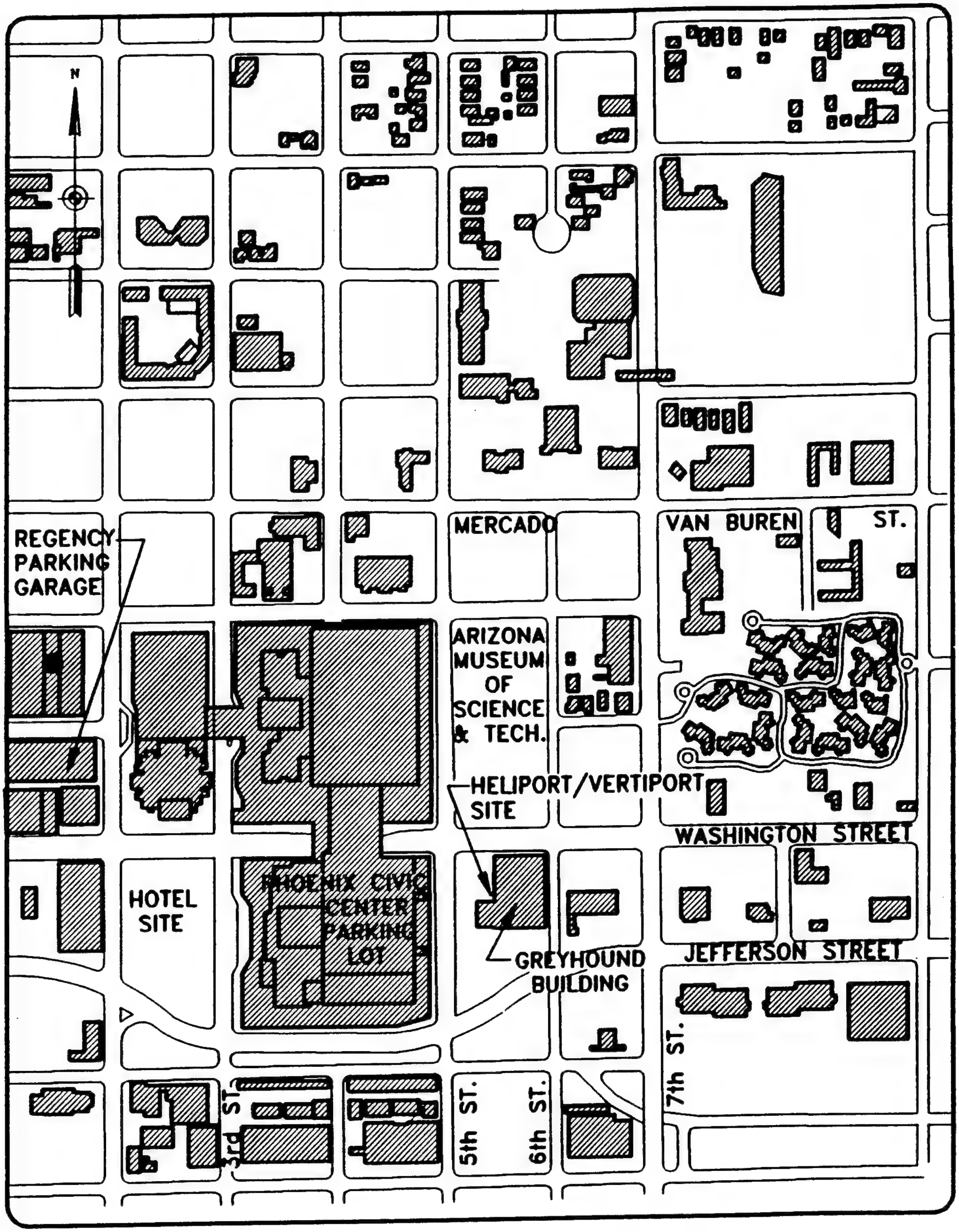


FIGURE 27 400 SCALE LOCATION PLAN - CINCINNATI



1 inch = 400 feet.

FIGURE 28 400 SCALE LOCATION PLAN - PHOENIX

In terms of airspace, it is located within a Prohibited Area (P-56) that protects the U.S. Capitol Building and the White House. As noted in the Airman's Information Manual (AIM) published by FAA (reference 25), a Prohibited Area contains:

> "...airspace of defined dimensions identified by an area on the surface of the earth within which the flight of aircraft is prohibited. Such areas are established for security or other reasons associated with the national welfare. These areas are published in the Federal Register and are depicted on aeronautical charts."

Since Union Station is within a P-56, flights to and from a vertiport situated in this airspace would not be possible unless the prohibited area was modified to permit these flights. However, for the purposes of this analysis it is assumed that future regulations would allow flights to Union Station. The Union Station is surrounded by government facilities, primarily office buildings (see figure 29). The roof of the parking garage immediately north of Union Station was used for this large heliport/vertiport siting analysis. The dimensions of the parking garage roof are approximately 220 feet by 420 feet.

3.1.4 Suburban - New Vertiport, Mansfield, Texas

The City of Mansfield, Texas is part of the Dallas-Fort Worth "Metroplex." It is located 21 miles south of the Dallas-Fort Worth Airport (DFW), southwest of Dallas and southeast of Fort Worth. Mansfield is also approximately 10 miles northwest of the recently cancelled "Super Conducting Super Collider" project in Waxahatchie, Texas. The vertiport site under consideration is located in southeast Mansfield next to U.S. 287 and a proposed right-of-way for state highway 360 that will connect U.S. 287 with the city of Arlington to the north. As currently proposed, it is bounded on all four sides by public roads. The site is made up of approximately 180 acres of farm land (see figure 30).

The advantage of studying a site like Mansfield is that it is undeveloped. It can therefore be developed incorporating all the necessary facilities, numbers of TLOFs, parking spaces, etc., required for its current needs and future potential without constraint from existing development. Careful planning can safeguard the airspace and provide adequate noise and environmental protection for its future neighbors.

3.1.5 On-Airport - JFK International Airport, New York, New York

The Port Authority of New York and New Jersey (PANYNJ) undertook a major master plan for JFK International Airport in the mid-1980's, referred to as JFK-2000. One of the major recommendations presented in that master plan was to develop a new central terminal building known as the Transportation Center. Two studies sponsored by the PANYNJ subsequently recommended that a rooftop heliport be incorporated into the design of the proposed Transportation Center. The Transportation Center was to link the various individual terminals at JFK by a new people mover system. The JFK-2000 program has since been significantly scaled down due to high costs, and the most recent plans for the Transportation Center do not include a rooftop with the structural integrity to support a heliport. If a heliport/vertiport were to be included, the existing plans would have to be modified.

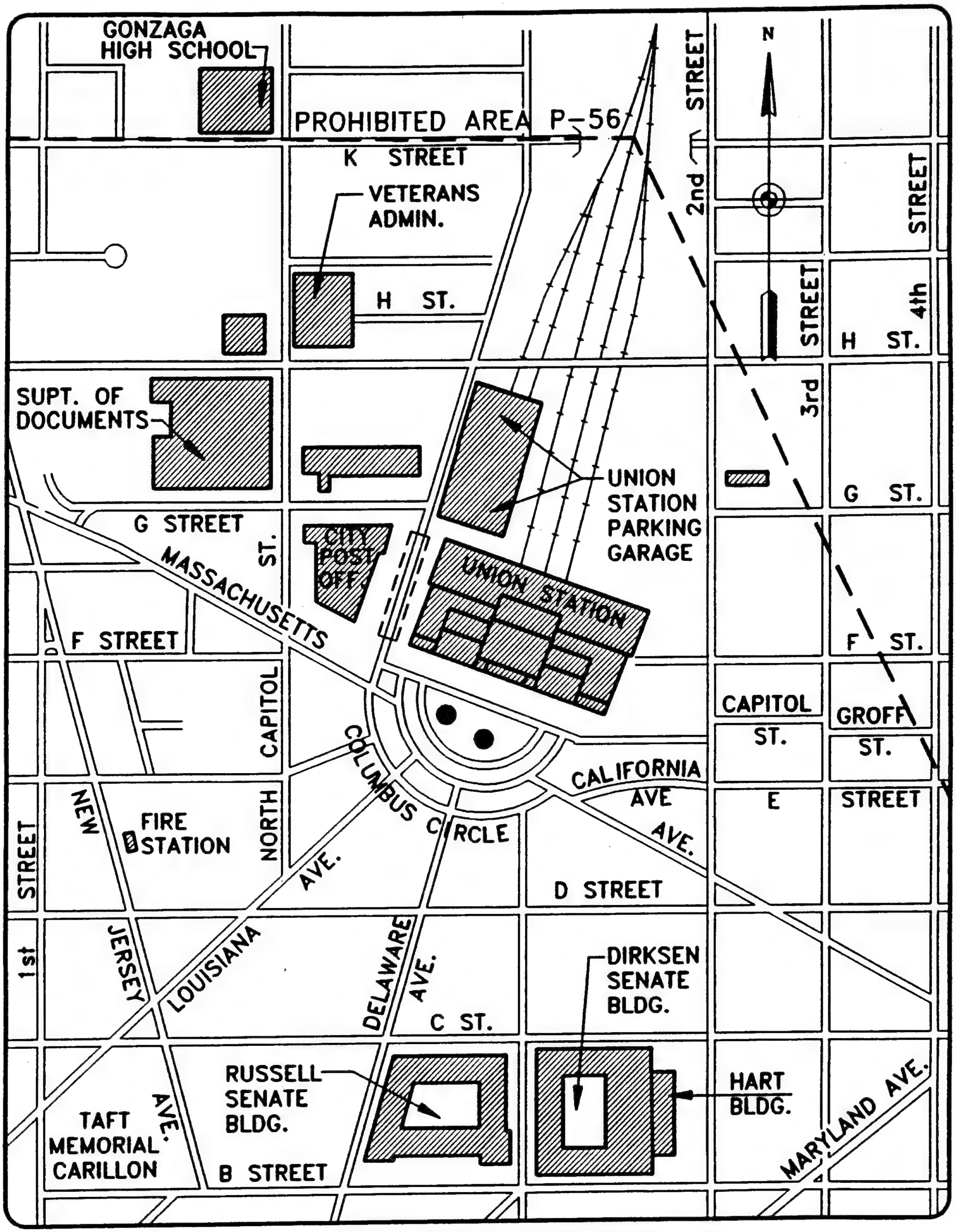


FIGURE 29 400 SCALE LOCATION PLAN - WASHINGTON, D.C.

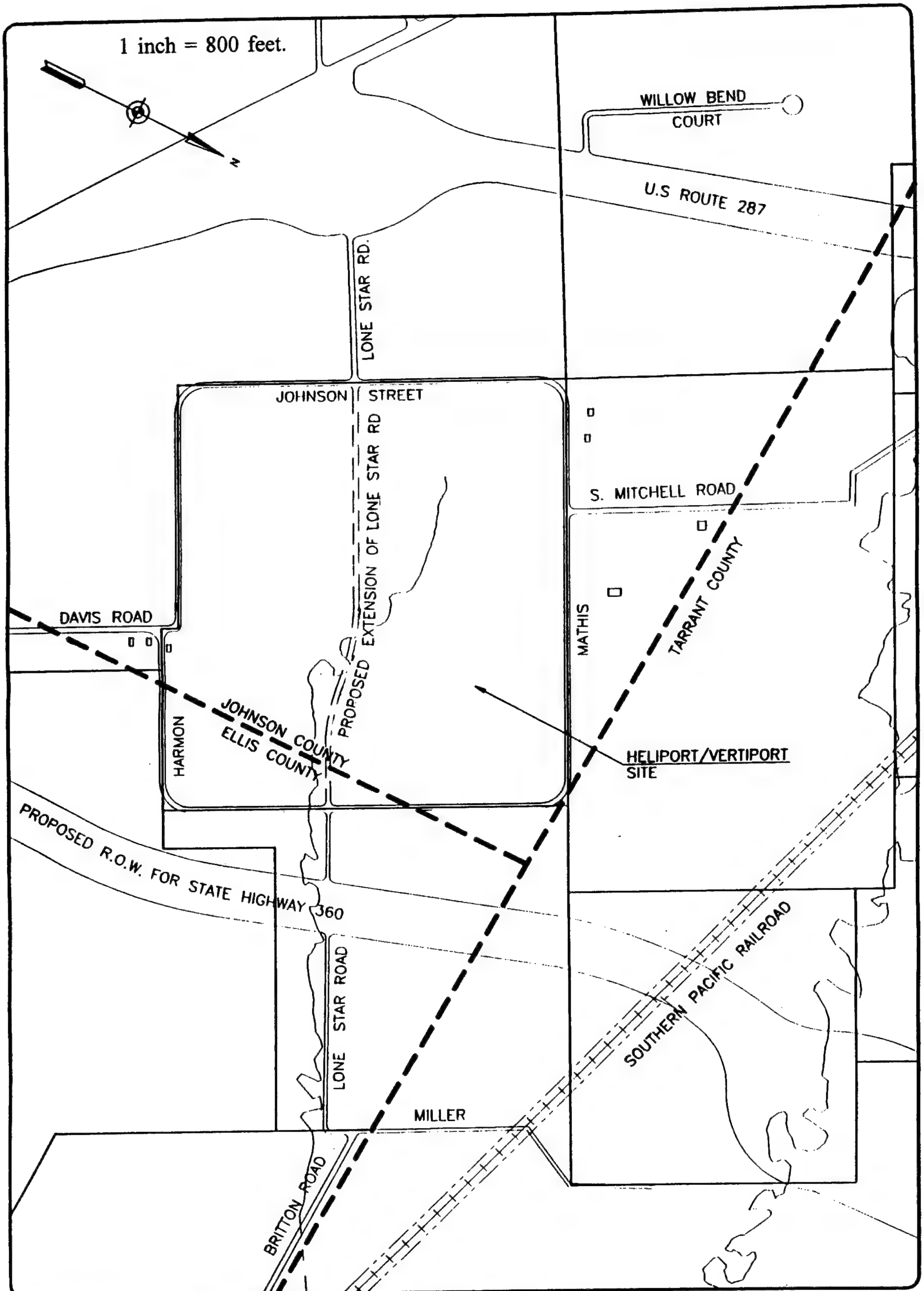


FIGURE 30 400 SCALE SITE 4 IN MANSFIELD, TEXAS

An alternative proposal was to locate a 1,000 foot by 2,000 foot heliport/vertiport maneuver area at ground level northwest of the terminal complex. The approximate boundaries would be the terminal apron to the southeast, taxiway "R" to the southwest, taxiway "O" to the north, and taxiway "V" to the east. The aircraft would land at the TLOF, taxi to parking positions, and passengers would proceed to the gates at the existing terminal (see figure 31).

If plans for expansion of American Airlines facilities are fully carried out, there may not be sufficient room for vertiport facilities. However, development of the area described in the previous paragraph appears more feasible than locating a vertiport on the roof of a future Transportation Center. It was assumed for this analysis that a 1,000 foot by 2,000 foot area would be available for a landing area and that the existing gates and terminal facilities would be used for CTR terminal functions. However, as shown on figure 31, taxiways "O" and "I" are being relocated toward the cargo area. The PANYNJ stated that relocation of the taxiways will provide additional space for ramp and terminal expansion. A number of designs for expansion of the terminal are being reviewed as of this writing. The PANYNJ plans to expand the terminal building into the area provided by relocation of taxiways. Though the timing of such changes is indefinite, it was assumed that the area described above would be available for development of a vertiport.

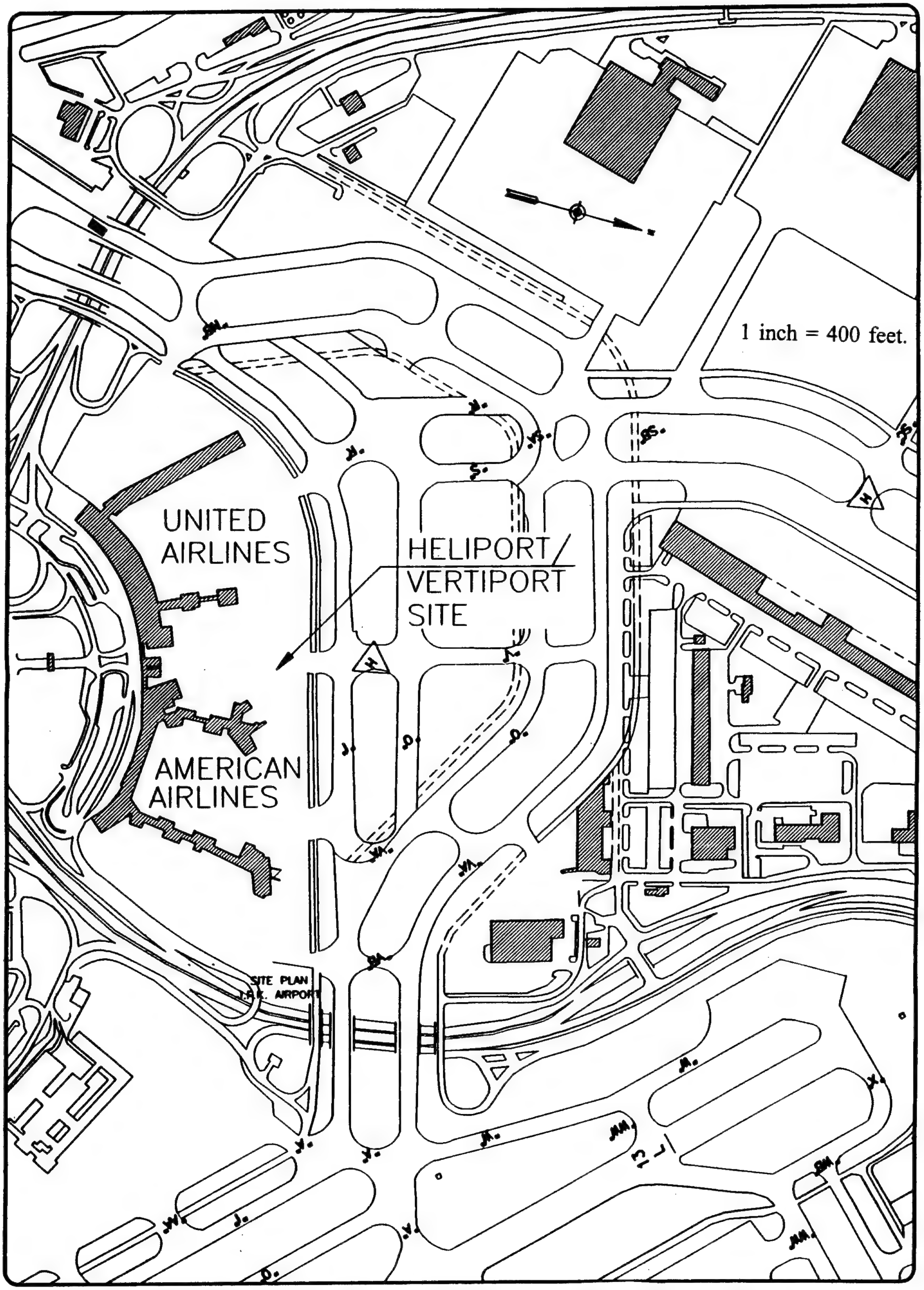


FIGURE 31 400 SCALE SITE 5 AT JFK, NEW YORK

4.0 OPERATIONAL CAPACITY/FACILITY REQUIREMENTS

This section contains a discussion of general capacity requirements and facility requirements related to airside operations. Airside issues discussed in this section include capacity to support peak hour and annual demand, takeoff and landing area requirements, and aircraft parking area requirements. The general airside requirements are established and then applied to each site to determine the adequacy of the sites described in section 3.0.

As a result of the work documented in this section of the report, the FAA concluded that additional vertiport capacity analysis was required. The results of this analysis were published in DOT/FAA/ND-95/3, "Vertiport Capacity - Analysis Methods," (reference 3). At this point, this analysis defines the cutting edge of vertiport capacity analysis. Interested parties would be well advised to read reference 3.

4.1 PEAK HOUR/ANNUAL DEMAND CAPACITY

As is the case with airports, the capacity of a large heliport and vertiport is a measurement of the operational level that can be accommodated with a given standard of service (delay) within a given time period (usually annual, average day in the peak month, or peak hour). FAA AC 150/5060-5, "Airport Capacity and Delay" (reference 26), provides a method of calculating annual, daily, and hourly capacity and delay of runways, taxiways, and gates. These calculations are based on various levels of ATC services offered, VFR versus IFR, runway configurations, exit taxiways, and gates. FAA heliport and vertiport ACs do not address capacity and delay, therefore, this analysis is based primarily on reports that have been published to date that focus on airport capacity.

Two factors have made it difficult to measure heliport capacity: 1) the FAA has not developed a heliport/vertiport capacity manual or other technique to identify facility requirements such as number of TLOF's based on peak hour demand, and 2) most civilian heliports (with the exception of bases on the Gulf Coast supporting off-shore energy exploration) generate very low levels of activity, so there are few examples of high activity facilities upon which to develop capacity models.

Two reports sponsored by the FAA analyzed activity data at the Indianapolis and Wall Street Heliports, the "Indianapolis Downtown Heliport - Operations Analysis and Marketing History" (reference 27) and the "New York Downtown Manhattan (Wall Street) Heliport - Operations Analysis" (reference 28), both of which are FAA prototype demonstration public-use heliports. These are the best two examples of comparatively high activity public-use heliports with reasonably good data records. At Wall Street, activity is relatively evenly spread throughout the year with very few large peaks in activity. That is consistent with a facility that attracts primarily business and corporate users. The Indianapolis Heliport had stronger peaks during the summer months, with a very strong peak of activity in May during the Indianapolis 500 motor race. Both these heliports have a separate single TLOF and FATO, a rotorcraft parking apron, as well as hangar facilities.

At Wall Street, activity peaked in 1985 at 34,480 annual operations, declining to 18,342 operations by 1989. In terms of operational capacity, the Wall Street Heliport is the best example of continuous year-round high activity at a public-use facility. During 1985, the year with the highest annual operations, activity was actually conducted at Battery Park Heliport, while the Wall Street Heliport was being reconstructed. The Battery Park Heliport had a single separate TLOF and parking apron, yet accommodated an estimated 18 peak hour operations in the absence of ATC ground control. The peak hour operation estimate is based upon data presented in the report "Feasibility of Manhattan Sites for Civil Tiltrotor Service," reference 29. These data indicate that peak hour operations, as weighted toward data for airline shuttle operations, can be expected to be 2.2 times the number of non-peak hour operations. These data were acquired by the FAA from 10 major United States airports during the calendar year 1978. The range of the data varied from 1.6 to 2.27 with the 2.27 value being the Boston-New York shuttle market. An additional unpublished value, calculated from Indianapolis Heliport operations records, indicates that the peak hour ratio is around 2.0 for purely rotorcraft operations.

It is likely that a heliport that experiences very strong peak month and peak hour activity, even with 30,000 annual operations, would experience some delays during those peak periods. Furthermore, this estimated peak hour capacity is based on a heliport where the most common aircraft are light to medium *helicopters* with relatively few passengers. Large scheduled service CTR aircraft with many passengers to enplane and deplane would likely take significantly longer to accommodate. At what point those delays would occur, how extensive they would be, and the actual turn-around time for scheduled passenger CTR aircraft, is difficult to estimate without a capacity model or site-specific or aircraft-specific capacity surveys.

4.1.1 Peak Hour Capacity

In the process of studying CTR operations in the report "Civil Tiltrotor Missions and Applications Phase II: The Commercial Passenger Market" (reference 19), NASA estimated that each operation by a CTR will require 6 minutes at the TLOF and 30 minutes at a gate (turnaround time). An operation in this context is defined as either a takeoff or a landing. Using this rationale, and assuming an adequate number of gates, each TLOF would be expected to accommodate 10 operations per hour. However, this assumption is very dependent on vertiport configuration. A TLOF with only one taxiway would be severely limited in operations. A TLOF with a rollway of 400 feet and a taxiway on each end would probably be capable of operations much like a conventional fixed-wing runway. One CTR could easily land and taxi to a gate while another CTR completed takeoff checks on the second taxiway. Upon completion of the checks, the majority of the 6 minute period, the CTR would taxi onto the TLOF and immediately takeoff. This TLOF/taxiway configuration might easily be capable of more than 20 operations per hour with appropriate gate space. Therefore, peak hour capacity is not necessarily TLOF dependent, but instead it is vertiport-layout dependent. In fact, a study by the University of Maryland (reference 30) indicates that the number of gates may be the critical capacity constraint since most vertiports will be constrained in size by land availability issues. Likewise, the 6 minute

TLOF time is only a baseline value for conducting analyses. At present there is no CTR operational experience to confirm the validity of this number.

A second study, "Vertiport System Planning for the Boston Area" (reference 31), uses a more conservative method in defining peak hour capacity. This method assumes that a CTR-22C will use 3 minutes to taxi-in/taxi-out between the terminal and the TLOF, 6 minutes occupying the landing pad (TLOF), and 1 minute for flight clearance. This method also assumes that taxi-in/taxi-out operations can occur simultaneously. The 1 minute wait for clearance can also be completed at the gate position. The resultant capacity of a single TLOF, as calculated using this method, is nine operations per hour with the required gate space.

Using both the study results and observations associated with possible vertiport configurations, a range of peak hour capacity values must be assumed as being valid for calculating the required number of TLOFs. This calculation is made as follows:

$$T = PHO/OPSH$$

where,

T = Required number of TLOFs
PHO = Number of peak hour operations
OPSH = Limit number of operations per hour

If a vertiport expects 45 operations during the peak hour, the facility would need 5 TLOFs and an adequate number of gates if each TLOF was somehow constrained to 9 operations per hour. However, this answer does not make intuitive sense in that a large number of gates will be needed to handle this many peak operations. If more than five gates are available, it is quite probable that enough land is available for construction of a rollway with taxiways at each end. This vertiport configuration might allow 20 or more operations per hour with few delays. Using these values, it appears that two TLOFs are probably adequate.

This variation in the results clearly indicates that the FAA needs to sponsor additional research to improve the peak hour capacity methodology. This research must address the impact of vertiport layout on TLOF capacity and the estimation of the time required on the TLOF or taxiway immediately prior to takeoff or after landing (during this occupancy time, the TLOF can not be used for another operation).

4.1.2 Annual Capacity

The calculation of an annual capacity for any vertiport configuration requires that numerous assumptions be made. For the example calculations presented in this section, the following assumptions are considered as baseline.

- CTR-22C seating capacity is 39 passengers; a conventional passenger rotorcraft seating capacity is 30 passengers;

- the average load factor is 63 percent (the load factor used most frequently in recent vertiport studies (reference 32) was between 60 and 65 percent);

- vertiport operations are conducted 52 weeks per year, 5 days a week, 14 hours per day (a number of recent vertiport studies assumed that operations would be conducted 5 to 6 days a week, 14 hours per day); and

- peak hour operations equal 2.2 times the number of average hour operations (see section 4.1).

Calculation of the number of TLOFs required to meet annual capacity is obtained using the following equation.

$$T = \frac{(AOPS)(2.2)}{(W)(D)(H)(OPSH)}$$

where,

T = Required number of TLOFs
AOPS = Number of annual operations
2.2 = Peak hour operations ratio
W = Number of weeks of operation per year
D = Number of days of operation per week
H = Number of hours of operation per day
OPSH = Limit number of operations per hour

Conversely, the annual capacity of a vertiport that exhibits the assumed peak hour characteristics with a single TLOF (T = 1) can be calculated as follows:

$$ACAP = \frac{(OPSH)(W)(D)(H)}{2.2}$$

where,

ACAP = Annual capacity (in operations)
OPSH = Limit number of operations per hour
W = Number of weeks of operation per year
D = Number of days of operation per week
H = Number of hours of operation per day
2.2 = Peak hour operations ratio

The resulting calculations indicate that with a 9 operations per hour limit the annual number of operations is 14,891 operations per year. With a different vertiport configuration, where one TLOF will support at least 20 operations per hour, the annual number of operations is 33,091 per year.

In summary, while the above calculations are required for planning purposes, it cannot be emphasized enough that the calculations are only approximate in nature. Further research and eventually the trial operation of a CTR system will be required to verify these calculations and the assumptions. At this point in time, too many of the variables are dependent on vertiport configuration factors and operational requirements that are not yet defined for CTR aircraft.

4.2 TAKEOFF AND LANDING AREA REQUIREMENTS

Like helicopters, the CTR is capable of vertical takeoff with no horizontal acceleration although with decreased range and/or payload. However, providing an area for horizontal acceleration prior to climb greatly enhances the utility and economic return of the CTR by allowing it to operate with higher payloads, especially on hot days and/or at high elevations.

4.2.1 Rejected Takeoff (RTO) Requirements

Based on CTR operating characteristics, Category A operations are assumed to require an RTO distance of 400 to 1,600 feet from the center of the TLOF, assuming that a regulation comparable to 14 CFR 29, "Transport Category Rotorcraft," will be developed for passenger-oriented CTRs. All CTRs above a certain maximum takeoff weight/seating capacity will have to be capable of Category A performance.

4.2.2 Normal STOL/VTOL Distances

The benefits of providing horizontal acceleration capabilities at a vertiport/large heliport were described earlier in section 2.4.1. The "Vertiport Design" AC (reference 2) recommends an elongated TLOF of approximately 400 feet whenever possible to take advantage of "significant operational and economic benefits." The current Dallas vertiport includes a 360 foot rollway. The rollway will ultimately be expandable to a length of 1,000 feet. Current testing also shows the benefits of a rollway or clearway of approximately 1,000 feet in length. The rollway allows the CTR the efficiency of improved aerodynamics to provide an increased payload to empty weight ratio for a fixed available power level. Additional advantages of STOL capabilities at a vertiport are fuel savings, reduced training costs, decreases in noise exposure, and increased CTR engine and transmission life, as well as increased safety margins.

4.2.3 TLOF/FATO Dimensions

The TLOF is a hard or paved surface capable of supporting the CTR for final landing and takeoff. The AC "Vertiport Design" (reference 2) shows minimum TLOF dimensions to be 100 by 100 feet for VFR operations and 150 feet by 150 feet for IFR operations. The AC recommends a TLOF of at least 400 feet in length to provide rollway capabilities for the improved operating characteristics described in sections 4.2.1 and 4.2.2. For these reasons, a TLOF width of 100 to 150 feet and a TLOF length of 100 to 400 feet is applied to each

site analyzed. In addition, the AC recommends that the maximum longitudinal and transverse slopes of the TLOF should not exceed 1 percent.

The FATO is defined in AC 150/5390-3 as "a defined area in which the final phase of the approach maneuver to a hover or landing is completed and from which a takeoff maneuver is commenced." The FATO typically contains and extends beyond the TLOF. If the TLOF is not centered within the FATO with the primary axis centered on the final approach course (FAC), the FATO must include at least 75 feet of clear space between the edge of the TLOF and the edge of the FATO. The AC also recommends that the length of the FATO be increased by 50 feet per 1,000 feet of elevation above 1,000 feet MSL for the reasons discussed in section 2.4.2.

The AC recommends minimum dimensions of a FATO to be 250 feet by 250 feet for visual approaches. For purposes of this study, it is assumed that the FATO extends at least 75 feet beyond the edge of a TLOF for those TLOFs with visual approaches. The AC recommends a 300 foot by 300 foot FATO for nonprecision instrument approaches, a 250 foot wide by 550 foot long FATO for 9-degree precision instrument approaches, and a 300 foot wide by 1,225 foot long FATO for 6-degree precision instrument approaches. The AC states that the maximum slope of paved sections and unpaved sections of the TLOF should not exceed 1 percent and 1.5 to 5 percent, respectively.

4.2.4 Final Approach Reference Area (FARA)

The "Heliport Design" AC defines the final approach reference area (FARA) is an area surveyed by location and elevation, and approved for instrument operations where hover or touchdown is authorized. It is normally associated with a FATO that is designed to support a precision instrument operation. It provides a 150 foot obstacle-free square where instrument procedures may terminate or begin. The center point, or helipoint, is aligned with the FAC and designated as an arrival and/or departure point for reference and control of instrument arrival and departure operations of helicopters. Because its current dimensions are less than the FATO, it has been assumed not to affect real estate or design requirements.

4.2.5 Lighting

Lighting requirements for vertiports, as discussed in paragraph 42 of FAA AC 150/5390-3, show figures depicting typical lighting for a vertiport with STOL capabilities and a vertistop. The basic FATO and/or TLOF lighting system must be enhanced if the TLOF/FATO is to accommodate a precision instrument procedure. Heliport instrument lighting systems (HILS) are extensions of the TLOF edge lights. The lines of HILS extend 150 feet before and after the TLOF and 45 feet on either side of the TLOF. A HALS extends from the approach edge of the TLOF for a distance of 1,000 feet.

Visual cues (recognition of obstacles, parking areas, etc.) and depth perception decrease rapidly at night. Flight tests in a UH-1 helicopter (reference 33) have shown that 25 percent additional tip clearance is required to compensate for deterioration of visual cues

in low ambient lighting. CTR simulators are currently being used to assess the adequacy of vertiport lighting and marking.

Ongoing vertical flight research being conducted at NASA Ames (reference 34) through simulation tests in a CTR simulator showed the following preliminary results with regard to vertiport lighting.

- Pilots preferred precision approach path indicator (PAPI) lights rather than visual approach slope indicator (VASI) lights.

- The PAPI lights would provide useful guidance, especially while the CTR is executing steep approaches.

- NASA simulation testing has indicated that a significant portion of the current HALS system appears to be "behind" the pilot during 9-degree approaches. This effect of the HALS being "behind" the pilot is especially evident when the CTR is descending out of clouds at 200 feet MSL (Category I minima) and is only 1,200 feet from the TLOF.

HALS are required to be installed as part of a precision instrument approach. They also serve to lower visibility minimums for straight-in non-precision approaches as well, but are not required for non-precision approaches. Large heliports and vertiports that accommodate scheduled service will need precision instrument approaches, including HALS, in order to maintain the same level of reliability as fixed-wing airlines serving airports do today. Large heliports and vertiports should have instrument approach minimums of at least 200 feet and 1/2 mile (Category I).

4.2.6 Marking

Marking requirements for vertiports are discussed in paragraph 41 of AC 150/5390-3 (reference 2). The standard pattern for marking the vertiport TLOF is the "broken wheel" measuring 28 feet in diameter.

The NASA simulator testing cited in section 4.2.4 (reference 34) also addressed marking. These tests have shown a number of concerns regarding current vertiport marking standards:

- The 28 foot "broken wheel" is adequate for a VFR TLOF (100 feet by 100 feet). However, tests show that at the current size, the broken wheel design does not provide suitable landing guidance under IFR conditions. It has been suggested that it be increased to 100 feet for IFR TLOFs (150 feet by 150 feet).

- Even if the broken wheel is painted at a diameter of 100 feet, a CTR approaching on center at an angle of 9-degrees blocks almost 1/2 of the broken wheel marking from the pilot's view.

  A 1967 report, "Development Study for a Helipad Standard Marking Pattern," (reference 35), recommended a minimum pattern size of 75 feet to be identifiable from a distance of one mile and a viewing angle of 5-degrees. Both the Maltese Cross and the "broken-wheel" pattern were ranked very highly in the results of this test program. While the Maltese Cross was initially selected as the standard heliport marking symbol, it was later dropped when a single individual complained that it was an anti-semitic symbol. In 1991, the FAA adopted the "broken-wheel" as the standard vertiport marking symbol (reference 2).

- Low visibility conditions further reduce the pilot's ability to see the broken wheel. The broken wheel marking should be lighted.

- The 28-foot broken wheel looks like an "X" (the symbol for a closed facility) at a distance of approximately 200 feet.

- Since almost 1/2 of the TLOF is obscured from the pilot's vision on a 9-degree approach, additional guidance is required outside of the normal TLOF area. Recommendations for improved guidance include:

  - providing lines extending out from the center of the TLOF on 45-degrees radials, or

  - providing lights on the radials that would "point back" to the TLOF from the opposite side.

4.2.7 Pavement Design

FAA AC 150/5320-6C, "Airport Pavement Design and Evaluation" (reference 36), provides guidance on pavement design. The AC "Vertiport Design" states that dynamic loads (which are based on MGTOW) imposed by the most critical CTR, the heaviest expected to ever use the facility. Current figures show the CTR-22C would have a MGTOW of 46,230 pounds, which is significantly higher than conventional rotorcraft. (The EH-101 would have a MGTOW of 31,500 lbs., and the S-92 a MGTOW of 22,000 lbs.)

The CTR-22C has two sets of dual wheels for its main gear. The tire contact area is 105.8 square inches over the four tires of the main gear, and 28.8 square inches over the two tires of the nose gear. The vertiport design AC say that dynamic load should be 150 percent of the static load, with 75 percent of the resultant load distributed through the main gear. Therefore the dynamic forces on the main gear and the nose gear are as follows:

Main Gear:

$$MTOW \times 150\% = DL$$

$$DL \times 75\% = DLm$$

$$\frac{DLm}{(SIT \times N)} = PDLm$$

where,

MTOW = maximum takeoff weight, pounds
DL = dynamic load, pounds
DLm = dynamic load on main gear, pounds
SIT = square inch per tire
N = number of tires
PDLm = pounds of dynamic load on main gear in pounds per square inch (PSI)

Therefore,

$$46{,}230 \times 150\% = 69{,}345$$

$$69{,}345 \times 75\ \% = 52{,}009$$

$$\frac{52{,}009}{(105.8 \times 4)} = 122.89, \text{ rounded to 123 PSI on main gear}$$

Nose Gear: Since the main gear dynamic load is 75 percent of the total, then the nose gear is 25 percent of the total dynamic load. This can be figured by subtracting main gear dynamic load from the total dynamic load as follows:

$DL - DLm = DLn$, then PSI on nose gear can be calculated by,

$$\frac{DLn}{(SIT \times N)} = PDLn$$

where,

DLn = dynamic load on nose gear
PDLn = pounds of dynamic load on nose gear PSI

Therefore,

$$69{,}345 - 52{,}009 = 17{,}336$$

$$\frac{17{,}336}{(28.8 \times 2)} = 300.97\text{, rounded to 301 PSI on main gear}$$

The structural strength of a rooftop or ground level TLOF, taxiway, or parking apron, should be based on the higher dynamic load on the nose gear of 301 PSI.

It is recommended that the TLOF and aprons be constructed of portland cement concrete (PCC) to support dynamic loads of the CTR. PCC greatly resists rutting and grooving and also engine exhaust when the nacelles are tilted vertically when taxiing. Bituminous pavement, on the other hand, is very susceptible to rutting and grooving, particularly in very hot weather, and from melting under the heat of engine exhaust. Bituminous pavement is less expensive to install. At airports bituminous pavement is typically only used on aircraft parking aprons.

FAA AC 150/5390-3 also recommends that a 25 to 35 foot wide light duty paved shoulder be constructed around the edges of all operational surfaces (FATOs, vertiport taxiways, and aprons) to minimize potential blowing dust from rotorwash.

4.3 AIRCRAFT MANEUVERING, SEPARATION, AND PARKING REQUIREMENTS

CTR parking requirements are a function of the size of the CTR expected to use the facility, separation between parking spaces, and the number of spaces required based on the level of activity.

4.3.1 Maneuvering Space

The size of the TLOF and the FATO are discussed in section 4.2.3. CTRs would maneuver from the TLOF to the apron by hover taxiing over a hover taxiway or wheel taxiing on a ground taxiway. The vertiport design AC recommends that for a paved taxiway, the paved portion should be 75 feet wide. PCC is the recommended pavement when aircraft are expected to generate heat that would be directed downward, because as PCC provides a heat and blast resistant surface. Safety areas for taxiways should be 250 feet wide for a hover taxiway and 150 feet wide for a ground taxiway.

Simulator testing at NASA Ames shows that current CTRs exhibit problems with lateral stability during ground taxiing due to the narrow wheel tread (distance between right and left main gear) and large forces and moments centered about the tips of the wing (reference 34). Recommendations to improve the lateral stability are not yet available.

Operational experience may indicate that the minimum vertiport taxiway widths and safety areas need to be increased over the standards currently in the AC. Per the AC, longitudinal and transverse grades of taxiways should not exceed 2 percent, while transverse grades of up to minus 3 percent are permitted in the taxiway safety area.

4.3.2 Separation Criteria

4.3.2.1 TLOF and FATO Separation

There are no separation criteria for TLOFs/FATOs published in FAA AC 150/5390-3. However, the AC does include a recommendation that the FATO measure at least 250 feet by 250 feet, which results in a minimum separation of 250 feet between centers of FATOs.

Additional separation can be provided by locating a TLOF at each end of an elongated FATO. With such an arrangement, two CTR landing areas can make use of the same FATO, thereby minimizing the amount of area required.

Simultaneous IFR operations currently require a minimum of 3,300 feet separation between runways. Consequently, simultaneous IFR operations at TLOFs located at opposite ends of a single FATO are not expected to be practical or permissible.

4.3.2.2 Taxiway Separation

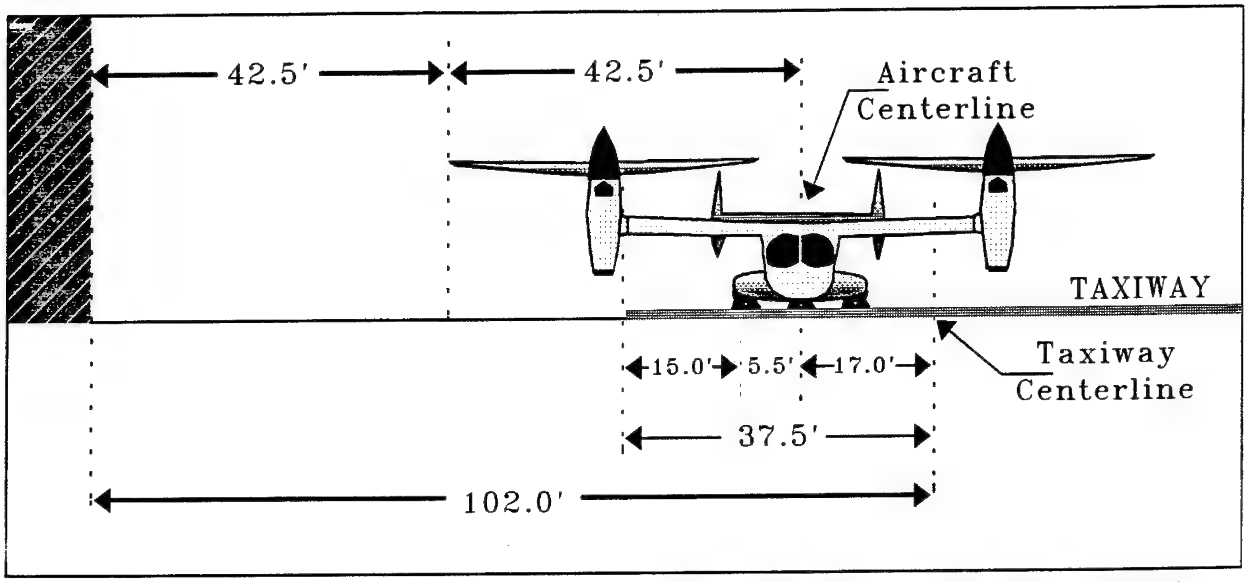
Ground Taxiway. The AC recommends a minimum of at least 1/2 of the tip-to-tip span (42.5 feet for a CTR-22C), but not less than 25 feet of separation between the rotor tip of an aircraft and a fixed or moveable object with the aircraft's undercarriage 15 feet from the edge of a taxiway. The recommended width of the vertiport taxiway is 75 feet. With the edge of the CTR-22C's undercarriage 15 feet from the edge of a taxiway, the engine and rotor on that side would extend over the edge of the taxiway. This means the distance from the taxiway centerline to the farthest tip of the rotor extended over the edge is 59.5 feet (1/2 tip-to-tip span 42.5 plus an additional 17 feet from the aircraft centerline to the taxiway centerline). Adding on the minimum separation distance (1/2 half the tip-to-tip span) of 42.5 means that there must be a minimum of 102 feet between the centerline of a vertiport taxiway and a fixed or moveable obstacle. An example is presented in figure 32.

Hover Taxiway. For a hover taxiway, the AC recommends a minimum of 75 feet of clearance between the rotor tip of an aircraft on the centerline and a fixed or moveable obstacle (see figure 33). Again, applying the dimensions of the CTR-22C:

	42.5 feet	One half of the tip-to-tip span
+	75.0 feet	Required minimum clearance
=	117.5 feet	The required separation distance between the centerline of a hover taxiway and a fixed or moveable obstacle

4.3.2.3 Rotorwash Research

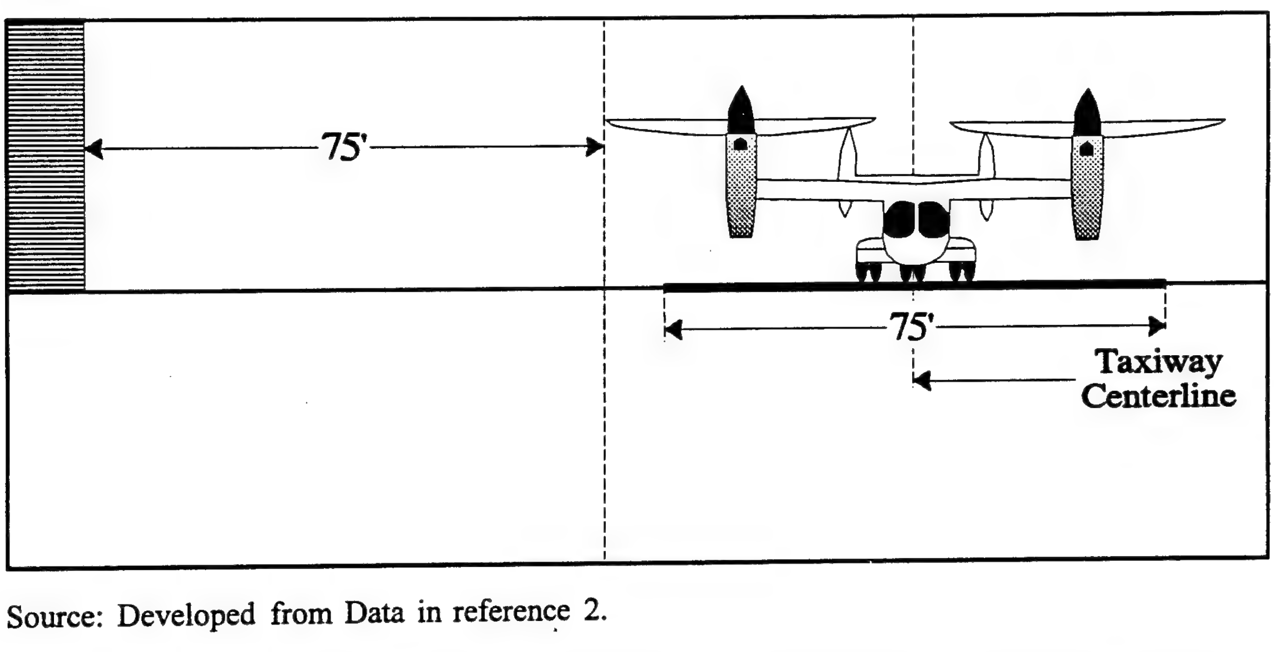
When helicopters or CTRs are flown in a confined area or in close proximity to ground personnel and other aircraft, the potential exists for rotorwash related problems. The FAA-sponsored research documented in the "Rotorwash Analysis Handbook" (reference 37) addresses this safety issue. Use of this reference allows for the estimation of the effects of



Note: Distance between rotor tip and a fixed or moveable object varies with size of rotor tip-to-tip dimension, cannot be less then 25 feet.

Source: Developed from Data in reference 2.

FIGURE 32 EXAMPLE OF SEPARATION CRITERIA - GROUND TAXI



Source: Developed from Data in reference 2.

FIGURE 33 EXAMPLE OF SEPARATION CRITERIA - HOVER TAXI

various levels of rotorwash on ground personnel, structures, other rotorcraft, and light fixed-wing aircraft.

Data documented in reference 37 also define a relationship between ease of controlled movement by various size classes of personnel as a function of varying force levels that result from CTR rotorwash flowfields. One group of military trained test subjects, grouped by height and weight, have evaluated the rotorwash flowfields for several types of rotorcraft. Data for the 2nd, 15th, 50th, and 90th weight percentiles indicated that test subjects began to experience minor difficulty in walking when subjected to an oscillatory rotorwash force of approximately 30, 30, 50, and 60 pounds, respectively.

The general public is expected to be affected by much lower values of rotorwash generated force than trained military personnel. For the purposes of this study, it is assumed that minimum setback distances from taxiways to areas of a vertiport used by the general public (such as boarding areas) should subject untrained personnel to rotorwash forces of no more than 30 pounds maximum.

4.3.2.4 Rotorwash Related CTR Taxiway-Aircraft Parking Separation Criteria

Results from the study of rotorwash related mishaps (reference 37) indicate that whenever peak rotorwash velocities exceed approximately 35 knots (40 miles per hour (MPH)), the potential exists for several types of serious mishaps. A related report (reference 38) indicates that a V-22 in an air-taxi maneuver, at a rotor height of 30 feet AGL, can generate 35 knot rotorwash velocities in the lateral direction from 150 to over 200 feet from the center of the nearest rotor. The range in distance results from the effects associated with aircraft gross weight, pitch/roll attitude, ambient wind velocity and direction, and atmospheric density. The distance from the center of the fuselage to the center of a rotor for the CTR-22C is 30 feet. Therefore, the distance from the center of a CTR-22C to an area where the rotorwash velocity is less than 35 knots would be 180 to 230 feet. It must be noted in terms of vertiport design that rotorwash effects can be very site- or scenario-dependent. This is the reason why reference 37 was developed along with numerous design examples that are included for reference.

Since an appropriate minimum separation distance between a vertiport taxiway and CTR-22C gate areas should be 180 to 230 feet, a distance of 200 feet was assumed for this study. This requirement would need to be increased to accommodate the effects of CTRs larger than the proposed CTR-22C.

Since an appropriate minimum separation requirement between vertiport taxiway and CTR-22C parking/boarding areas should be 180 to 230 feet, a distance of 200 feet was assumed for this study. This requirement should be increased to accommodate the effects of CTRs larger than the proposed CTR-22C.

4.3.3 Gate Requirements (Parking Positions)

The FAA advisory circular "Vertiport Design" recommends that each parking position equal the overall rotor tip-to-tip width of the design CTR aircraft. For the CTR-22C design aircraft, this distance is 85 feet. The AC further recommends a minimum separation distance between the limits of the rotor tip span and any fixed or moveable object, which includes other aircraft and parking positions, of one half the tip-to-tip distance. Therefore, the calculation of a gate parking position dimension for this analysis is presented as follows:

85 feet = tip-to-tip span of a CTR-22C

85/2 = 42.5 feet, rounded to 45 feet on each side

therefore,

85 + (45 x 2) = 175 feet, minimum width of each CTR-22C parking position

Note: If two or more adjacent gate positions exist, then the gate parking positions have overlapping separation distances; i.e., the 45 feet on either side of the adjacent positions overlap to still yield a 45 feet separation. Therefore, the total width of the required parking position will be calculated based on the total number of positions times 45 foot between each two positions. Two parking positions would require a 305 feet wide space (not 350 feet) due to the overlapping 45 feet.

Analysis from reference 38 recommends the ideal width for CTR-22C gate parking positions as being 360 to 460 feet. This "ideal" spacing distance avoids subjecting ramp personnel and CTR passengers to rotorwash velocities in excess of 35 knots during the worst case heavy weight air-taxi scenarios. Since rotorwash effects are primarily a function of rotor thrust (which is a function of gross weight), the minimum distance between CTR gate positions can be substantially reduced if the CTR is operated in a ground taxi rather than a hover air-taxi mode. This operational assumption, as recommended in reference 38, is carried forth in this research effort. Application of the air taxi based width requirement simply requires excessive infrastructure expense for a CTR facility.

Even though the recommendation for the use of a gate separation criterion based on ground taxi is believed to be a more functional criterion, calculation of a practical and useable gate separation width still involves some uncertainty. This uncertainty results from operational unknowns associated with scheduled CTR operations at a vertiport. If passenger loading/unloading takes place on the ramp unprotected from rotorwash effects while operations continue uninterrupted at adjacent gates, then the required gate separation width will be a maximum for passenger protection. If loading/unloading activity is allowed to be interrupted while aircraft arrive/depart at adjacent gates, then gate separation width will be

less. If passenger loading bridges are used, then activity will probably not be restricted along with the added benefit of enhanced vertiport security. Some helicopter operators have voiced their opinion that CTR operations may be conducted without engine shutdown (engine exhaust may be a problem) while rotors continue to operate at idle RPM.

Each of these example scenarios, which are not all inclusive, implies a different gate separation width and clearly involves tradeoffs between gate width and vertiport capacity. Land availability at many potential sites will also impact the tradeoffs involved. While safety must ultimately be a driving factor, all decisions as to which tradeoffs are made must ultimately rest with industry and vertiport designers. Therefore, additional research into these issues by the FAA is clearly warranted. It should be noted that test data for the rotorwash characteristics of a V-22 size CTR, as focused upon civil applications, have not yet been acquired. Military oriented evaluations of V-22 rotorwash characteristics are scheduled to begin in late 1995. However, it is not certain that these evaluations will collect all the data of interest from a perspective of civil operations.

This is a vertiport design tradeoff affecting safety, capacity, and land requirements (gate separations). When maximum capacity is needed, it will be desirable/required for CTRs at adjacent gates to operate independently. Thus, a CTR would be taxiing in or out while passengers are loading/unloading at an adjacent gate. Smaller gate separations would be acceptable if operations were restricted at adjacent gates (and the resultant loss of capacity was acceptable) or if loading bridges (similar in function to jetways) are used to protect passengers from rotorwash during loading/unloading. This is an important issue and must be called to vertiport designer/planners' attention. Additional R&D is required to more fully define the consequences of each of the options available. To be judged acceptable, all the options must be safe, however, the choice between options belongs to industry.

4.3.4 Number of Gates (Parking Positions) Required

As assumed in section 4.1, each CTR operation will require a turnaround time of 30 minutes at the gate position. The Manhattan study (reference 29) assumed the same turnaround time and recommended that the number of gates (parking positions) be based on the arrival rate (1/2 the number of peak hour operations since an operation is a takeoff or a landing) times the turnaround time of 0.5 hours.

The Manhattan study further recommended that the resultant number be multiplied by a factor of 0.95. The 95 percent factor accounts for gate inefficiency since mechanical delays, ATC delays, etc. will be encountered. One additional parking position over that calculated to be required is recommended to account for schedule changes, mechanical problems, etc. The resultant equation for calculating the required number of gates (parking positions) is:

$$\text{GATES} = (\text{PHO}/2)(0.5/0.95) + 1$$

PHO = number of peak hour operations

This equation can be used to calculate the number of gate positions required to support one TLOF at nine operations per hour where:

$$(9/2)(0.5/0.95) + 1 = 3.4 \text{ gates}$$

Table 4 presents the number of gates with the respective number of TLOFs under normal conditions at nine operations per hour per TLOF (see section 4.1.1 and reference 31) (note that the number resulting from the multiplication of 3.4 times the number of TLOFs must be rounded up).

TABLE 4 NUMBER OF GATES (PARKING POSITIONS) REQUIRED

Number of TLOFs	Number of Gates/Parking Positions
1	4
2	7
3	11
4	14
5	17

If the 30 minute turnaround time associated with current fixed-wing airline operations were slightly shortened due to the lower number of passengers, less luggage, shorter taxi times, etc., then the number of gates will be reduced. However, for this study the 3.4 gates per TLOF is assumed as a baseline value.

At some space-constrained sites, such as most elevated rooftop facilities, there may not be sufficient land area to accommodate the projected demand for gate positions, particularly when other operational constraints such as rotorwash are involved. Consequently, many previously identified vertiport sites may not be acceptable for the desired number of operations due to limited land availability.

5.0 PASSENGER SUPPORT FACILITIES

This section discusses the general requirements related to terminal buildings and other landside facilities, including cargo/baggage handling, automobile parking, rental car, and access roads. The CTR mission identified by virtually all operational scenarios reviewed in analysis of the recent vertiport feasibility studies (reference 32) was predominantly that of scheduled passenger service operations and to a lesser extent, executive transport, and cargo. The business traveller was defined as the predominant type of passenger in scheduled service operations (reference 32). Based on these findings, the following criteria were developed.

5.1 TERMINAL BUILDING REQUIREMENTS

The Manhattan study (reference 29) provided the most detailed calculations and rationale regarding terminal building and terminal area requirements, and is used as a basis for this analysis. Preliminary terminal building requirements are calculated using design parameters from the Terminal Facilities Programming Model (TFPM) that was used in the Manhattan study. The model combines operational data with terminal design parameters to estimate facility requirements. Other methods, programs, etc., are available for computing terminal building requirements, but the factors and assumptions of the TFPM can be changed to apply to local conditions if different from the assumptions used in the Manhattan study. Key assumptions in that study were that CTR service would primarily be a business-oriented shuttle service and that the number of peak hour operations would be 2.2 times the number of average hour operations (section 4.1). As discussed in section 4.1, it is assumed that a vertiport is in operation 14 hours per day. Table 5 identifies the facility sizing parameters that were used in this study and the Manhattan study.

Except where noted, the rationale for the facility sizing parameters in table 5 was obtained from the Manhattan study and is presented in the following sections.

> <u>Passengers:</u> Business travellers would dominate the CTR market. These travellers would largely use the service for 1- or 2-day trips, with a minimum of baggage. Even within the peak hour, passenger activity would fluctuate. In airport planning, it is usually assumed that up to 50 percent of the peak hour activity occurs in the busiest 20 minutes of the peak hour. However, given the business orientation of most CTR passengers, it is reasonable to assume that more activity would occur in the busiest 20 minutes since these travellers are more prone to arrive at a terminal with minimum time to spare. Thus, it was assumed that 60 percent of the peak hour activity occurs in the busiest 20 minutes.
>
> <u>Visitors/Greeters:</u> Unlike most conventional airport facilities, very few visitors or greeters would be expected at a vertiport. Most departing business passengers would either be dropped off at the terminal by taxi, or automobile or would drive and park at the facility. Only a few visitors would incur the time and expense to park their

TABLE 5 FACILITY SIZING PARAMETERS

PARAMETER	VALUE	COMMENTS/SOURCE
1. Passenger Characteristics		
a. Percent With Baggage	30 percent	Assumption
b. Percent Transfer	0 percent	Business O/D Only
c. Peak Period	20 mins.	Industry Standard
d. Percent Peak Hr in Peak Period	60 percent	(Industry Standard 50 Percent)
2. Visitor/Passenger Data		
a. Visitor/Passenger Ratio	0.35	Assumption
b. Percent Visitors Through Security	0 percent	Assumption
3. Ticketing		
a. Manual Ticketing Rate (min/pax)	2.6	Industry Standard
b. Automatic Ticketing Rate	2.0	Assumption
c. Ticket Counter Frontage (ft)	6.0	Industry Standard
d. Area: Automatic Ticket Devices (sf)	60	Estimate
e. Ticket Lobby Area/Person (sf)	13	Industry Standard
4. Baggage		
a. Baggage/Pax Ratio	0.30	Assumption
b. Baggage Claim Frontage (ft/device)	108	Industry Standard
c. Percent Visitors In Claim Area	0 percent	Assumption - Manhattan Study
	15 percent	Assumption - This Study
d. Baggage Claim Area/Person (sf)	15	Industry Standard
5. Concessions/Public Services		
a. Gift & News Area/Pax (sf/10^6 Pax)	600	FAA Guidelines
b. Rental Car Area/Pax (sf/10^6 Pax)	400	FAA Guidelines
c. Rest Rooms Area (sf/500 Pax)	1,500	FAA Guidelines
6. Holdrooms/Security		
a. Holdroom Area/Pax (sf)	15	Industry Standard
b. Percent Peak Period Pax In Holdroom	90 percent	Industry Standard
c. Security Inspection Rate (Pax/Hour)	600	Industry Standard
7. Other Spaces		
a. General Circulation (percent Total Area)	20	Estimate
b. Mechanical/Electrical (percent Total Area)	10	Estimate

Source: Reference 39.

cars and accompany traveling associates to the vertiport. Similarly, the number of greeters would be limited. Overall, the ratio of visitors and greeters to passengers is expected to be less than that of a typical airport.

The Manhattan study assumed that following current industry practice, no visitors or greeters would be permitted into the baggage claim areas. For purposes of this study, it is assumed that 50 percent of the passengers in the terminal building and 15 percent of visitors and greeters will be in the baggage claim area.

Ticketing: CTR scheduled service would make extensive use of automatic ticketing devices. Traditional ticket counters would be used mostly for passengers with baggage or by pre-ticketed passengers who need boarding passes.

Baggage: No more than 30 percent of the total passengers are expected to use baggage services because the market would largely consist of business travellers on day trips. However, full baggage services would be required to expedite those that do. Passengers would be able to check in baggage, and would retrieve baggage at a bag claim area with a similar baggage rack.

Concessions/Services: The vertiport would have the traditional concessions available at airports, including a small restaurant/lounge, gift and newsstand, and rental car or limousine service counters. These not only provide services passengers now expect, but also contribute financially to the facility.

Holdrooms/Security: Security screening would be required for all passengers. This screening would occur before passengers enter gate holdrooms, and would ensure that no visitors would be permitted into secure areas.

Other Spaces: To estimate total terminal size, standard industry ratios (normal values applied by architects to net building square footage to approximate a building's gross square footage) were used for general circulation and mechanical/electrical areas.

The assumptions used in the Manhattan study for five different forecast periods result in a factor of 45 to 66 (average of 64) square feet of gross terminal building area being required per peak hour passenger. The capacity of each site to accommodate passengers will be calculated based on the size of terminal building that is feasible compared to the optimum space indicated by application of a factor of 64 square feet of terminal building per peak hour passenger.

5.2 PRINCIPAL SUPPORT COMPONENTS

5.2.1 Cargo/Baggage Handling Requirements

Except for the Puerto Rico/Caribbean Basin (reference 40) study, the CTR feasibility study review showed minimal demand for CTR cargo flights. Puerto Rico showed a demand for "point-to-point" CTR cargo service, either factory-to-factory or factory-to-airport. The demand for such service was based in part on the remoteness of demand centers within the Caribbean Basin, and the possible cost savings over fixed-wing cargo service and time and cost saving of other modes. If provided with a quick-change option, the passenger equipment in a CTR could be removed and used for cargo flights. The Manhattan study mentioned that belly hold (carried in the baggage compartment) cargo service could be offered during scheduled passenger flights and that all-cargo flights could be introduced once CTR scheduled passenger service is established. This type of cargo would be comprised mostly of express mail and small packages rather than large air cargo containers, whereas all-cargo flights evaluated in the Caribbean considered use of standard cargo containers.

The facilities that would be required at a vertiport to accommodate cargo or express mail and small package shipments are entirely dependent on the location of the vertiport (proximity to cargo originations/destinations), the type of businesses that would be served by the vertiport, and competing prices via fixed-wing and truck transportation.

Customs would be required at, or in close proximity to, a vertiport handling international shipments. Vertiports with significant cargo services may require off-loading and warehousing facilities with both airside and truck access.

For purposes of determining the adequacy of sites, it is assumed that facilities to accommodate any express mail or small package freight will be met by baggage facilities required for the passengers. Significant all-cargo and general cargo vertiport operations would require development of special-use facilities which would not be part of typical vertiport development.

A very simple facility is adequate to accommodate small package freight and the estimated 30 percent of passengers with bags to be checked. Because of the low volume of checked bags, only a bag rack will be required. This is a sloped shelf with access from the outside of the building through which the bags are delivered. The frontage of the rack allows the bags to be manually spread out for claiming by the passengers. This type of operation is similar to many fixed-wing commuter airline operations.

Baggage and small package freight would be handled by the operator of the passenger and/or freight service, i.e., the airline. Their area within the terminal would be used for processing of outbound bags and freight while the bag/freight claim area would be a

"common" area used by all. The claim area would ideally be located adjacent to the building entrance through which deplaning passengers would enter from the apron.

5.2.2 Automobile Parking/Rental Car/Access Road Requirements

As discussed previously, the predominant user of scheduled CTR service is expected to be the business traveller, although some studies such as the Puerto Rico study identified strong demand from other types of passengers such as resort travellers. Most arriving and departing business travellers would either be dropped off at the terminal by taxi, or automobile, or would drive to, and park at, the facility. Only a few visitors would incur the time and expense to park their cars and accompany travelling associates to the vertiport. Automobile requirements would then be generated by passengers and to a very limited degree by greeters. If the vertiport is not co-located with, or in close proximity to, taxi services or a multi-modal facility (buses, limousines, trains, subways, etc.), there would be additional demand for rental car services.

Actual auto parking/rental car/curb requirements would be a function of the modal split of passengers (percent of passengers who walk or use a taxi, bus, limousines, or an automobile), an assumed dwell time (time a vehicle remains in the parking position or curb), and an assumed number of persons per vehicle.

5.2.2.1 Automobile Parking Requirements

Typically, auto parking requirements are based on the number of average day enplanements. The following factors were used to calculate parking requirements to be applied to each site:

- a vertiport is in operation an average of 14 hours per day,
- the number of peak hour enplanements is 2.2 times the number of average hour enplanements,
- a CTR load factor of 63 percent,
- a factor of 0.65 public parking spaces per daily enplaned passenger (reference 41),
- a factor of 15 percent of public parking requirements for employee parking (reference 42),
- a factor of 380 sf per auto parking space (allowing for circulation), and
- a curb length 1.25 times the length of the terminal building (reference 42).

The resultant relationship for calculating auto parking requirements for peak hour enplaned passengers is:

$$\text{required parking spaces} = (0.65 \div 14) \times (2.2 \times \text{number of enplaned passengers})$$

The above relationships will be used to calculate the number of auto parking spaces accommodated at each site when applied to the estimated number of peak hour passengers.

5.2.2.2 Rental Car Requirements

Rental car concessions are necessary at commercial service airports and future vertiports. They typically require ticket counters, office space, and parking facilities adjacent to the terminal building. Rental car concessions can operate with approximately 500 square feet of terminal lease space for the ticket counter and office. That does not include passenger queuing space in the lobby area. A minimum of 5 to 10 spaces would also be leased for use by the company running the facility. Under FAA grant assurances, an airport/vertiport sponsor cannot permit a monopoly to operate at the facility, so space must be provided for at least two rental car concessions in each terminal.

5.2.2.3 Road Access

Road access from the nearest public road must be provided to the vertiport. The access road should have, as a minimum, two lanes each 12 feet wide and meet National Association of State Transportation Officials (NASTO) design criteria. The right-of-way for the road will also provide space for under-and-above-ground utilities.

Providing ease of access to a vertiport is important. Difficult access can be created for passengers in several ways (e.g., road congestion during peak periods, lack of signs showing the route to the vertiport, or inconvenient road layout, such as one-way streets) and often can discourage use of the vertiport. This has been proven with airports where there is no direct highway access and a knowledge of the local street network is needed to find the airport. Such factors have decreased airport use, but it is very difficult to quantify how much. Since the success of vertical flight is so dependent on closeness of the passenger to origin and destination and ease of access, these road access questions are critical for heliports and vertiports.

5.2.3 Passenger Access to Aircraft

Passenger access to the aircraft parking positions can be accomplished in a number of ways, depending on the type of vertiport. For rooftop vertiports, access can be gained by walking from the parking area if at the same level, elevator/stairs from a parking garage or street on a lower level, or elevator/stairs from a nearby parking area or multi-modal facility.

5.2.3.1 National Fire Protection Agency (NFPA) Requirements

The NFPA's "Standard For Heliports" (reference 43) requires that "two approved means of egress from the roof shall be provided and shall be remotely located from each other to the extent practical but shall not be located less than 30 feet from each other," for heliports occupied by more than 50 people, and "one approved means of egress from the roof shall be provided" for heliports occupied by less than 50 people.

For ground level vertiports, egress can be provided by walking to a nearby parking area or multi-modal facility. NFPA 418 also requires at least one access point for firefighters with a second route, where practical, as far as possible from the first access point.

5.2.3.2 Location Access Priorities

The location of a vertiport is important in terms of travel time. The vertiport studies showed that one of the most important factors that would encourage people to use vertical flight transportation would be reduced trip time from the point of origin to a vertiport compared to the time it takes to get to an airport. Vertiports located in urban areas to facilitate demand for city center service will, most likely, be constrained regarding space available for auto parking unless located on the roof of a parking facility. If such a constraint exists, it is recommended that the importance of locating the vertiport in close proximity to the passenger demand center take precedence over parking space. An urban setting will have sufficient alternatives to the automobile for providing access to the vertiport, e.g., taxi, limousine, subway, etc.

5.2.4 Terminal Building and Airfield Security

The requirements of 14 CFR 139, "Certification and Operation: Airports Serving CAB Certificated Air Carrier Aircraft," were discussed in section 2.6.3. Security requirements for airports (vertiports) certificated under 14 CFR 139.335, "Public Protection," are discussed in the following sections. Such requirements would need to be part of any vertiport accommodating scheduled service by aircraft with 30 seats or more.

5.2.4.1 Passenger Screening

14 CFR 139.335 requires that certificated airports provide measures to prevent inadvertent entry to movement areas by unauthorized persons or vehicles, to protect persons and property from aircraft propeller wash, jet blast or rotorwash, and to comply with 14 CFR 107, "Airport Security." 14 CFR 107 requires certified airports to prepare and comply with a security program. Per paragraph 107.4, the security program for airports certificated under 14 CFR 139 that serve operators with aircraft of more than 30 seats but less than 61 seats must include a description of:

- the program to provide security of the air operations area in conformance with paragraph 107.13(a),

- law enforcement support necessary to comply with paragraph 107.15(b),

- the training program for those law enforcement officers to comply with paragraph 107.17, and

- the system used to maintain records as required by paragraph 107.23.

Passenger screening is not required at airports certificated under 14 CFR 139 unless departing passengers are deplaned in a sterile area at the first stop after departure. It is recommended that security screening facilities be required at each vertiport. It would be much easier from a scheduling point of view to establish security screening at every vertiport even if only some passengers are deplaning into sterile areas at some destinations. Trying to keep track of which flights will be deplaning into non-sterile areas and which will deplane into sterile ones lends itself to mistakes and inadvertent violations of both 14 CFR 107 and 139.

When CTRs and fixed-wing scheduled service passengers share a terminal, existing airport passenger screening facilities can be used for both. The same type of equipment can be used at stand-alone vertiports when required.

5.2.4.2 Access Control

At vertiports accommodating aircraft of more than 61 seats, 14 CFR 107.14 requires an access control system, more than just preventing inadvertent entry. This would apply to vertiports that support aircraft like the CTR-7500, a 75-passenger CTR considered in preliminary NASA/Bell-Boeing design studies. In addition, 14 CFR 107.13(a) presents requirements for control of the air operations area (the areas of the "airport designed for the landing, taking off, or surface movement of airplanes"). These are listed below.

- Controlling access to each air operations area, including methods for preventing the entry of unauthorized persons and ground vehicles. This includes fencing, locked doors, etc.

- Controlling movement of persons and ground vehicles within each air operations area, including, when appropriate, requirements for the display of identification.

- Promptly detecting and taking action to control each penetration, or attempted penetration, of an air operations area by a person whose entry is not authorized in accordance with the security program.

5.2.4.3 Law Enforcement Officer Requirements

A certificated airport must have law enforcement officers that are available and committed to respond to an incident at the airport. Law enforcement officers that are used to comply with 14 CFR 107.15(b) requirements must:

- have the authority to make arrests without warrant for any crime committed in the officer's presence or a felony if the officer has reason to suspect a person committed the felony,

- be readily identifiable by uniform and badge,

- be armed with the authority to use a firearm, and

- have completed the required training program.

It would be beneficial to have law enforcement officers present on airport property for a suitable time prior to scheduled service operations, during scheduled service operations, and for a suitable time after scheduled service operations. However, a number of certificated airports do not have law enforcement officers at the site during scheduled service operations. Rather, state/county/local officers are called to an incident at the airport in much the same manner as to any other incident in a community. There are no guidelines for response time for law enforcement officers to respond to an incident at an airport, but this is generally achieved within 5 to 10 minutes. Because the vertiport sites analyzed in this study are in urban or metropolitan areas or at an airport, it is assumed law enforcement officers would be available from local sources and would be able to respond to an incident within the recommended time.

6.0 AIRCRAFT SUPPORT FACILITIES

Vertiports, as defined in the operational scenarios of almost all the feasibility studies, are "full service" vertiports. The term "full service" has come to mean that the facility provides passenger support (terminals, rental car/parking facilities, etc., as discussed in section 5.0) and aircraft support (fueling and limited maintenance capabilities). This section contains a discussion of primary aircraft support services, fuel, maintenance, aircraft rescue and firefighting (ARFF) facilities, and other services such as de-icing equipment, automated surface observation systems (ASOS), etc.

6.1 PRIMARY SERVICES

6.1.1 Maintenance Facilities

The vertiport feasibility studies (reference 32) contained discussions of maintenance requirements. The studies did not plan full maintenance facilities unless the location was an operational hub and/or was in an area where sufficient real estate was available. Otherwise, maintenance was limited to that which could be accomplished overnight at the parking areas. No additional land would be required for this type of maintenance other than the parking position itself. Full maintenance services, airframe and powerplant (A&P), and avionics may be feasible at major hub locations or at vertiports located at airports.

Full maintenance services require hangar(s), related parts, and work areas. For purposes of this study, the size of a maintenance hangar is calculated based on a 20 foot wide area around each aircraft maintenance space using the CTR-22C as a model. It is assumed that this area will accommodate enough space for parts storage, work areas, and office space. Key CTR-22C dimensions are a tip-to-tip span of 85 feet and an overall length of 69 feet. Total gross area of maintenance hangar per CTR maintenance space is then calculated to be approximately 13,600 square feet. Such hangars may also provide space for storage of CTRs when not required for aircraft maintenance. Maintenance aprons, in addition to parking positions, should be provided at locations that require full maintenance services. Maintenance aprons are assumed to require the same area as parking aprons, approximately 14,340 square feet (see section 4.3.2).

6.1.2 Fueling Facilities

Fueling services will be required at each vertiport accommodating scheduled service, unless fuel could be obtained at another vertiport on the same route. To travel off-route to obtain fuel was assumed to be not cost beneficial for the CTR, particularly those in scheduled service.

It is expected that fuel system requirements for vertiports will be the same as for heliports, except that more fuel will need to serve the larger aircraft. Turbine fuel will be required at those vertiports providing fueling services. The required storage capacity of a CTR fueling

system at a vertiport would be a function of the level of activity and the supplier's minimum quantity of fuel dispensed per delivery.

The NFPA's 1990 "Standard For Heliports," #418 (reference 43), requires fuel storage tanks to be located at least "50 feet from the edge of takeoff and landing areas..." Fuel storage tanks would have to be at least 50 feet from the TLOFs and FATOs. This standard also requires at least one access point for fire fighters with a second route, where practical, as far as possible from the first access point.

The NFPA's 1992 "Aircraft Fueling Ramp Drainage," #415 (reference 44), requires aircraft fueling ramps to slope away from hangars, terminal buildings, aircraft loading walkways, or other structures at a minimum grade of 1:100 for the first 50 feet, and 1:200 for the remainder of the vertiport surface.

The NFPA's 1990 "Aircraft Fuel Servicing," #407 (reference 45), prescribes standards for design and operation of aircraft fuel systems. The Vertiport Design AC (reference 2) recommends that if trucks are to be used to fuel CTRs, the vertiport should be arranged to minimize the need for the trucks to cross the TLOFs, FATOs, or taxiway system.

It is expected that trucks would be used only at locations that are not space constrained. A number of municipal ordinances do not permit rooftop fuel systems (e.g., Cincinnati, Ohio, one of the selected sites in this research report). Access to rooftop vertiports and heliports by truck is valuable not only for fueling, but also for emergency vehicles as well. In fact, all rooftop facilities should provide vehicle access to the rooftop, even if truck refueling is not anticipated. Providing access to all rooftop facilities with vehicle access ramps will significantly increase operational safety by providing the ability of emergency vehicles to respond to situations on the roof. Without such access ramps, emergency vehicles could not reach the roof and therefore not provide adequate response.

Many local building codes require that the buildings on which rooftop fueling is allowed be served by separate drainage systems that will collect not only runoff from rain and snow, but also fuel and oil that may be accidentally spilled, as well as aqueous film forming foam (AFFF), which is typically used as a firefighting agent. Such contaminants typically cannot be allowed to drain into a municipality's drainage system without treatment. Contaminants such as fuel, oil, and AFFF must be collected and stored, and either treated on-site or else taken to a treatment facility for disposal.

Oil-water separators are often installed as part of the facility's drainage system on airport parking aprons that accommodate high volumes of air carrier activity, even if the apron has a separate drainage system. Separators are, however, expensive to install.

6.1.3 Aircraft Rescue and Firefighting (ARFF)

Guidance in FAA AC 150/5390-3 shows that 14 CFR 139, "Certification and Operations: Land Airports Serving Certificated Air Carriers," is expected to apply to vertiports offering scheduled passenger service. This regulation is applicable because the expected design aircraft, the CTR-22C, has a seating capacity of more than 30 passengers (39). The AC mentions that vertiports not offering scheduled passenger service should apply the fire protection standards of the NFPA.

14 CFR 139 requires a maximum response time of 3 minutes from alarm for the first response vehicle to reach the midpoint of the furthest air carrier runway and begin to dispense agent, and 4 minutes for all other vehicles to reach the same point and respond. 14 CFR 139 prescribes ARFF requirements using an index system based on the length of the aircraft. The length of the CTR-22C is less than 90 feet (69 feet), so the applicable index would be A. Per 14 CFR 139, Index A vehicle and agent requirements are as follows:

> "One vehicle carrying at least -
>
> (1) 500 pounds of sodium based dry chemical or halon 1211; or
>
> (2) 450 pounds of potassium based dry chemical and water with a commensurate quantity of Aqueous Film Forming Foam (AFFF) to total 100 gallons, for simultaneous dry chemical and AFFF foam application."

NFPA provides that required fire protection can be handled with portable extinguishers, one fire extinguisher at each takeoff and landing area, parking area, and fuel storage area. Since the CTR is 69 feet long, NFPA requires a minimum fire extinguisher rating of 10-A:120-B. Portable fire extinguishers are not required at unattended ground level heliports. (It is assumed that all vertiports would be attended).

NFPA requires rooftop heliports to have additional fire protection. Rooftop heliports must have a foam fire protection system designed and installed to protect a practical fire area (PFA). The PFA for the CTR-22C would be approximately 766 square feet. The three types of foam typically used are ARFF, fluoroprotein foam, and protein foam. Required quantities of water and discharge rates to accommodate the PFA of the CTR-22C are defined in table 6.

Per NFPA 418-6, a foam system is not required for:

- parking garages,
- elevated structures that are not on buildings and are not normally occupied, or
- other similar structures.

TABLE 6 TYPES OF FIREFIGHTING FOAM

Type of Foam	Quantity Of Water (U.S. gal)[1]	Discharge Rate (gpm)[1]
Aqueous film Forming Foam (AFFF)	199	100
Fluoroprotein Foam	276	138
Protein Foam	306	153

[1] Assumes a semi-fixed system.
Source: NFPA.

The NFPA's 1992 "Airport Water Supply Systems for Fire Protection," #419 (reference 46), requires the following minimum water flow rates for a terminal building to be 1,000 to 3,300 gallons per minute (gpm). The NFPA's 1990 "Aircraft Hangars," #409 (reference 47), requires aircraft hangars to be protected by both sprinklers and foam, the latter being either AFFF, low expansion foam, or high expansion foam. Based on a 13,600 square foot hangar, a water application rate of 2,312 gpm would be required, as well as an AFFF application rate of 1,360 gpm.

The preceding discussion is taken from applicable NFPA standards. Local building codes may have different requirements. The design of the vertiport must accommodate suitable access by emergency response personnel. Access to a ground level facility is usually provided via controlled gates. Access to a rooftop facility should optimally allow response vehicles to reach the same floor as the TLOF, but at a minimum, should allow emergency vehicle access to the floor immediately below the TLOF.

6.2 OTHER EQUIPMENT

Other equipment that may be required at a vertiport includes de-icing equipment and weather reporting systems. De-icing equipment applies to both the facility itself, as well as for the aircraft. While the discussion below focuses on maintaining a clear facility, aircraft also require de-icing to provide reliable service during the winter.

6.2.1 De-icing Equipment

6.2.1.1 Facility Snow and Ice Removal

Snow should be kept clear of aircraft movement surfaces at a vertiport so aircraft can maintain proper friction with the ground surface. The AC 150/5390-2A, "Heliport Design," (reference 1) recommends that at least the TLOF and as much of the FATO as possible be kept clear of snow. Rolling takeoffs are possible at some heliports and may be possible at some vertiports. However, a more important reason for keeping TLOFs and FATOs clear of snow is to maintain visibility. The downwash from helicopters and CTRs operating in helicopter mode cause snow on TLOFs and FATOs to be blown about and possibly obstruct a pilot's vision.

Operators of rooftop heliports report that snow removal is relatively easy and ice accumulation is typically not a problem. This is because snow typically blows off the elevated surface before it can accumulate and turn into ice because of prevailing winds over the tops of buildings (reference 48). Typical snow removal methods are shown in table 7.

TABLE 7 SNOW REMOVAL METHODS

METHOD	DESCRIPTION	SNOW LOAD WHERE MOST EFFECTIVE	EFFECTIVE AVERAGE TEMPERATURE
Mechanical	Includes shovels, plows, brooms, etc.	Greater than 5 pounds/sf.	Below 15-degrees F.
Mechanical/Chemical	Includes a non-corrosive chemical (urea or ethylene glycol), to break the ice, to surface bond/snow, and mechanical removal to remove build up.	Greater than 5 pounds/sf.	Greater than 15-degrees F.
Pavement Heating	A heat distribution system inside the pad surfaces to maintain the temperature of the pad/surfaces above the freezing point of water.	Greater than 5 pounds/sf.	Greater than 15-degrees F.

Source: Reference 48.

In addition, the specific snow/ice removal method that is used depends on wind characteristics and whether or not the vertiport is raised higher than the surrounding ground, e.g., is on a rooftop or is elevated in some manner. The report contains a method to calculate the cost-benefit of each method.

6.2.1.2 Aircraft Snow and Ice Removal

Glycol is typically used to de-ice aircraft, and is frequently applied by truck. The U.S. Environmental Protection Agency (EPA) requires that when glycol is used, it be collected and treated (similar to fuel and oil), and not allowed to drain into public drainage systems. It is recommended that glycol be available for aircraft de-icing as needed during winter months to ensure schedule reliability.

6.2.2 Weather Observation Requirements

Weather observation and reporting are not required to support visual flight operations. Despite this, most VFR facilities normally provide a limited amount of weather-related information as a safety feature to enhance operability.

When IFR operations are conducted by commercial aircraft (those operating under 14 CFR 135, 121 or 125, and 127), FAA regulations require that hourly and special weather observations be taken during the hours and dates when instrument activity is conducted. They further require that these observations be "expeditiously" provided to the ATC

authority having jurisdiction over the airspace associated with a particular heliport or vertiport.

Where the weather duties are conducted by other than Federal employees, the appropriate FAA office must notify the non-Federal employees about reporting and dissemination requirements and applicable National Weather Service (NWS) and FAA publications. The introduction and approval of automated weather devices is one way of satisfying this requirement. Guidance can be found in AC 150/5220-16A, "Automated Weather Observing Systems (AWOS) for Non-Federal Applications" (reference 49), as well as the heliport design AC (reference 1). Another non-government system for reporting weather is the ASOS, discussed in section 6.2.2.1.

6.2.2.1 Automated Surface Observation System (ASOS)

As stated in FAA's AIM (reference 25):

> The ASOS is the primary surface weather observing system of the United States. ASOS is designed to support aviation operations and weather forecast activities. The ASOS will provide continuous minute-by-minute observations and perform the basic observing functions necessary to generate a Surface Aviation Observation (SAO) and other aviation weather information. An ASOS includes the following:
>
> - Individual weather sensors,
> - data collection package(s) (DCP),
> - the acquisition control unit, and
> - peripherals and displays.
>
> The ASOS sensors continuously sample and measure the ambient environment, derive raw sensor data and make them available to the collocated DCP. Every ASOS contains the following basic set of sensors:
>
> - Cloud height indicator (one or possibly three),
> - visibility sensor (one or possibly three),
> - precipitation identification sensor,
> - freezing rain sensor,
> - pressure sensors (two sensors at small airports; three sensors at large airports),
> - ambient temperature/dew point temperature sensor,
> - anemometer (wind direction and speed sensor), and
> - rainfall accumulation sensor.
>
> An ASOS is recommended at every vertiport that is not located at an airport with either an ASOS or AWOS.

7.0 INTERMODAL CONNECTIONS

7.1 SITE EVALUATION

Intermodal transportation is defined as the interconnection of different modes of transportation. Many of the current transportation development efforts described as intermodal are focused on the reduction of automobile use. Such development is not really intermodal but the replacement of one mode by another. True intermodal development is that where two or more different kinds of transportation systems connect and riders from one system can easily transfer to another.

Other modes of transportation present both an opportunity for, and potential competition to, future large helicopter and CTR operations. As these aircraft will be used primarily for public transport, any form of transportation which offers such service may detract from their ridership. However, it is just as likely that other modes may supplement, enhance, and facilitate CTR/large helicopter traffic.

Different vertiport settings will have varying opportunities for intermodal integration or competition. The five locations analyzed in this study illustrate these differences and are presented in table 8. In addition, each vertiport setting is analyzed for "intermodal" opportunities that may present themselves, not through shared ridership, but through shared facilities. When supporting public transportation modes are able to share facilities, they all can become more efficient through reduced overhead and increased appeal to passengers.

Multi-use of transportation facilities should be encouraged as part of vertical flight facility development because it broadens the "constituency" of support, as well as providing additional sources of income for all transportation services sharing a location. Intermodalism is a logical concept in the minds of both the public and regulatory agencies that have significant input into the formation of policy regarding the development of transportation facilities. Consequently, it is recommended that vertiport facility development promote, where possible, shared-use facilities as an integral part of the design concept, whether the site is strongly geared to passenger transportation or whether it is a less complex heliport supporting other helicopter missions.

TABLE 8 INTERMODAL POTENTIAL AT THE FIVE SELECTED SITES

SITE	LOCATION	TYPE	ADDITIONAL MODE(S)	COMPETITION	OPPORTUNITY
Union Terminal	Cincinnati, Ohio	ground level	Intercity Rail	Minimal opportunity for shared ridership.	Allow common use of road access and parking facilities. Shared use of terminal building.
			Automobile parking, limousine, and taxi.		Required by most users.
Greyhound Bus Parking Garage	Phoenix, Arizona	elevated	Intra-city Bus	Limited opportunity for shared ridership. Most people using vertical flight are not expected to take public bus transportation.	
			Automobile parking, limousine, and taxi.		Required by most users. Can share parking facilities with local, non-vertical flight riders.
Union Station	Washington, D.C.	elevated	Intra-city light rail (Metro).		Potential for shared use of the terminal facilities.
					Significant opportunity. Surface connections through adjacent metro station to many destinations within DC.
			Inter-city rail (Amtrack)	Limited opportunity for shared ridership.	
			Automobile parking, limousine, and taxi.		Required by most users. Can share parking facilities with local, non-vertical flight riders.
			Walking		Situated within 2 blocks of the U.S. Capitol Building, Senate, House, and their office buildings.
JFK International Airport	New York, New York	ground level	Scheduled Air Carrier	Short haul flights would compete.	Bring in persons who would use vertical flight to other connections or final destination.
					Potential for shared use of terminal facilities.
			Automobile parking, limousine, and taxi.		Required by most users.
					Potential for shared facilities with local, non-rider users of parking.
New Vertiport	Mansfield, Texas	ground level	Automobile parking, limousine, and taxi.		As a new site designed to be constructed on a completely empty site, supporting transportation modes can be built-in.

Source: Hoyle, Tanner & Associates, 1993.

8.0 LAND USE PLANNING

Currently, one of the primary reasons that proposed heliports have not been constructed is because of the lack of public acceptance. Consideration of safety and environmental concerns is essential for public acceptance. Although noise is always a primary environmental issue, additional environmental questions are being encountered.

Transportation is an integral component of city infrastructure and rotorcraft are becoming a vital component of transportation. Heliports and vertiports bring aircraft right into the community, thereby raising public concerns. However, heliports/vertiports can be effectively integrated into both aviation and intermodal transportation systems when all the processes of development, from construction to community issues, are understood and addressed by those responsible for proposing and implementing the development.

This section discusses requirements for physical integration of the facility through obstacle clearance and public acceptance through considering concerns with on- and off-vertiport/heliport zoning and compatible land use as related to noise, economics, and social issues. Also, typical elements of a model zoning ordinance are discussed.

8.1 COMPATIBLE LAND USE

In general, compatibility with airport operations, in this case heliport or vertiport, is typically related to uses compatible with a given level of noise generated at the facility. Such compatibility is also related to precluding or at a least minimizing off-airport uses that would impair airport operations.

8.1.1 Noise Compatibility

A number of reports have discussed CTR noise levels. At this point in time, estimated CTR noise levels are based on extrapolations of noise generated by XV-15 and V-22 aircraft. The XV-15 (8 passengers) has a VTOL maximum gross weight of approximately 13,500 pounds (increasing to approximately 15,000 pounds in the STOL mode) (reference 19), where the CTR-22C (39 passengers) has a maximum gross weight of 46,350 pounds. As an initial estimate, the Bell-Boeing Team has extrapolated noise contours for the V-22 by assuming a 3 decibel (dB) increase per doubling of gross weight, assuming a CTR-22C weight of 45,000 lbs.

Noise levels of 75 dB day-night average sound level (L_{dn}) are generally considered to be compatible with land uses that are NOT very sensitive to ambient noise such as railyards, freeways, industrial parks, amusement parks, mining, fishing, and resource extraction (reference 50).

With incorporation of noise level reduction (NLR) measures, the following land uses are generally thought to become compatible with airport operations: ground transportation, automobile parking, government facilities, offices, retail trade, and manufacturing.

L_{dn} levels of 65 dB or less have historically been considered compatible with most residential and other noise sensitive land uses (references 50 and 51). At present, no tiltrotor noise levels are contained in either the FAA's Integrated Noise Model (INM) (reference 52) or Heliport Noise Model (HNM) (reference 51). CTR noise data will need to be added to both of these noise models in order to develop effective planning tools to adequately determine potential noise problems and compatible land uses.

Vertiport planners and developers would do well not to rely too heavily on the continued acceptability of the 65 L_{dn} contour. As the environmental sensitivity of the nation's citizens continues to increase, voices are being raised concerning the adequacy of the 65 L_{dn} contour and the adequacy of the L_{dn} metric itself. Although the L_{dn} is a sophisticated metric, some community planners are concerned that it is no longer adequate. They argue that a more sophisticated metric needs to be developed, perhaps one that provides even heavier weighing to nighttime operations. In addition, they argue that the 65 L_{dn} is too noisy and that, even with a different metric, a quieter contour line should be selected for vertiport siting in the vicinity of residential housing. Exactly how these issues will be resolved is far from clear. However, if CTR operation as a scheduled commuter is to be a success, environment considerations and compatible land use planning must be of paramount concern.

While the L_{dn} contour continues to be used by the FAA to identify impacts to noise-sensitive land uses, additional research should provide a methodology for determining the L_{dn} 65 dB and L_{dn} 60 dB contours for CTRs in various flight configurations, such as landing, takeoff, and fly-over. Engineers at NASA-Langley (reference 19) estimate that continuing research may enable the industry to produce a CTR aircraft roughly 10 dB quieter than the military V-22 version. More recent NASA/industry discussions have indicated that a 9 to 12 dB improvement over the V-22 is possible. Research will be required to reach this goal.

8.1.2 Land Use That Impairs Facility Operation

Land uses that can impair airport operations include those that create obstructions to imaginary surfaces and are classified as hazards to air navigation (see section 2.6.1), as well as those that interfere with aircraft operations. Examples of interference include electronic signals that disrupt navigation and communication between the vertiport and aircraft; off-vertiport high-intensity lighting and laser light displays that make it difficult for pilots to distinguish the landing site at night or in reduced visibility. Also of concern are situations that create bird strike hazards (such as landfills); or otherwise endanger or interfere with the landing, takeoff, or maneuvering of aircraft intending to use the vertiport.

8.2 HELIPORT/VERTIPORT ZONING

Municipal/regional comprehensive land use plans should address the development, operation, and location of vertiports and heliports within their community. After adoption

of appropriate land use plans, zoning ordinances should be enacted or revised to accommodate the findings of the land use planning effort.

Airport zoning regulations typically address two issues: a) protection of imaginary surfaces, and b) provision of measures to control surrounding land uses to maximize compatibility with the community. Municipal zoning regulations typically address issues such as compatibility among land uses. The FAA, in grants offered through the Airport Improvement Plan (AIP), requires that sponsor's proposals for airport improvements include the following assurances:

- the improvement will be reasonably consistent with local land use plans and/or zoning,

- the sponsor will mitigate or remove hazards to air navigation,

- the sponsor will take appropriate measures to restrict land uses in the airport vicinity to those uses normally compatible with airport operations.

The following are applicable excerpts from Part C of the Airport Improvement Program's Standard Title V Assurances, which will apply to vertiports if scheduled passenger service expands to anticipated levels. It states, "the sponsor hereby assures and certifies, with respect to this grant that:"

6. Consistency With Local Plans - The project is reasonably consistent with plans (existing at the time of submission of this application) of public agencies that are authorized by the State in which the project is located to plan for the development of the area surrounding the airport. For noise compatibility program projects, other than land acquisition, to be carried out on property not owned by the airport and over which property another public agency has land use control or authority, the sponsor shall obtain from each such agency a written declaration that such agency supports that project and the project is reasonably consistent with the agency's plans regrading the property.

7. Consideration of Local Interest - It has given fair consideration to the interest of communities in or near which the project may be located.

21. Compatible Land Use - It will take appropriate action, including the adoption of zoning laws, to the extent reasonable, to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations, including landing and takeoff of aircraft. In addition, if the project is for noise compatibility program implementation, it will not cause or permit any change in land use, within its jurisdiction, that will reduce the compatibility, with respect to the airport, of the noise compatibility program measures upon which Federal funds have been expended.

8.2.1 Zoning Ordinance Model

FAA AC 150/5190-4A, "A Model Ordinance to Limit Height of Objects Around Airports" (reference 53), provides a model zoning ordinance to limit the heights of objects constructed near landing facilities that may interfere with the most efficient operation of that facility. This AC can be used as a guide for developing appropriate zoning control. Although restricting infringement on airspace requirements is vital, other land-use issues also severely affect heliport and vertiport development and operation. The primary concern is noise-sensitive land uses, but there is a growing concern over issues pertaining to surrounding economic and socially compatible land uses. A model zoning ordinance (based on FAA's AC mentioned above), developed to be applicable to vertiports, is provided in appendix C of this report.

9.0 SUITABILITY OF VERTIPORT SITES

INTRODUCTION - Previous sections of this report discussed the operational requirements of CTR aircraft in terms of vertiports. In addition, planning issues such as land use, pavement design, and noise were also discussed. This section applies these criteria to specific sites at five real urban and suburban locations. Many of the sites have real-world constraints, such as limited space, obstacle-rich environments, and densely developed surrounding land uses. The results of applying these criteria to many of the sites, particularly those in urban areas, highlights the fact that vertiport design would be extremely limited in order to build and operate a public-use facility in most of these locations. Large heliports and vertiports, particularly those facilities that will accommodate scheduled service, should incorporate larger design criteria for areas such as TLOFs and FATOs to allow for maximum gross weight takeoffs, as well as sufficient space for emergency procedures.

The actual amount of real estate needed to support a large heliport or vertiport that could accommodate scheduled passenger operations is not easily found at existing sites in urban locations. This is the case even where passenger amenities and aircraft support services are minimized. Vertiports require dramatically less acreage than airports, even small general aviation (GA) airports. However, due to the nature of their operations, it would be a mistake to attempt to put a vertiport into too small an area. This can be seen in several of the examples identified in this section. In the long run, this would adversely affect future growth potential, reduce availability noise buffers, and negatively impact communities and public acceptance.

In order to maintain the level of safety required by 14 CFR Parts 135, 121, 127, 129, and 139, CTRs would have to operate at less than maximum gross weight at locations where there is limited rollway distance. This means the CTR will not have the opportunity to operate at maximum range or with full payload. This would impact the CTR operator's operating profits and competitiveness against fixed-wing aircraft. Thus there are economic considerations that dictate a requirement for a longer rollway than what is available at some of these example sites. Of even greater importance is the issue of emergency operations. Even with substantial weight limitations, a number of the example vertiport sites in this section are so small that CTR's could not operate safely in the event of a single-engine failure. Thus, for this reason alone, many of these sites would not be acceptable as public-use vertiports.

This is further exacerbated by constrained land use and limited space at many urban sites. These drawbacks would not allow the implementation of precision instrument approaches based on the criteria currently contained in the vertiport and heliport ACs (references 1 and 2), and in FAA Orders that address TERPS. For example, there is insufficient space at almost all of the example sites for the current HALS required for precision approaches, and for protecting the large imaginary surfaces for precision approaches.

This section illustrates some of the fundamental problems associated with developing existing sites and identifies some of the solutions to the real-world problems. It is important to note that for many operational areas of a facility, if sufficient space is provided to accommodate a CTR-22C aircraft, that same facility may also accommodate many conventional civil rotorcraft, including the EH-101 and S-92. In terms of facility planning for separation criteria based on size of aircraft, takeoff and landing performance, maximum gross weight, wake turbulence, and parking space requirements, the CTR-22C is assumed to be the critical design aircraft. References in this section to vertiport facilities, unless otherwise noted, are meant to imply that the conventional civil rotorcraft can be accommodated as well.

It must be noted that there is a vertiport design tradeoff affecting safety, capacity, and land requirements (gate/separations). When maximum capacity is needed, it will be desirable/required for CTR at adjacent gates to operate independently. Thus, a CTR could be taxiing in or out while passengers were loading/unloading at an adjacent gate. (There is also discussion in the industry about the possibility that the CTR would not shut down its engines while loading and unloading. In addition, since the CTR rotor blades are high twist blades, it would not be possible to operate them at "flat pitch.") Small gate separations would be acceptable if operations were restricted at adjacent gates (and the resultant loss of capacity was acceptable) or if something like "loading bridges" (jetways) are implemented to protect passengers from rotorwash during loading/unloading. Additional R&D is required to define more fully the consequences of each of the options available. To be acceptable, all the options must be safe, however, the choice between options belong to industry.

<u>DESIGN PROCESS</u> - The process for determining the layout of a vertiport and large heliport at each site is described in the following paragraphs. The recommendations presented in the previous sections of this report are expressed below as goals. The term 'goals' was used because it was realized that not all of the recommendations could be met at each site, although each conceptual layout was developed trying to incorporate as many recommendations as possible. Those goals were:

- A separate TLOF (or multiple TLOFs) will be located at each site. It is a goal of this analysis to provide a precision instrument approach or else a non-precision instrument approach where possible. It is also a goal to provide a 700 foot HMA, or rollway, where ever possible.

- The type of approach procedure that is provided is dependent on the size of the FATO that is possible, and the feasibility of providing a final approach fix and HALS.

- The determinant regarding whether an approach surface is appropriate for the desired type of approach procedure depends on whether required airspace surfaces are clear of obstructions.

- For this study, it is assumed that the existing structures will not be demolished for vertiport/large heliport construction unless such plans have already been made by the governmental body having jurisdiction over the site.

- It is assumed that the existing use of the general site area is to be maintained unless a change in use has been previously planned by the governmental body having jurisdiction over the site.

- After the TLOFs and FATOs have been located, the following priorities will be used to determine if additional facilities can be accommodated within the area remaining:

  - CTR parking positions and taxiways (if appropriate),
  - terminal building,
  - auto parking, and
  - access roads.

The following topics will be discussed for each site:

- airfield facilities and operational capacity,
- V/STOL performance requirements,
- ATC issues,
- terminal building requirements,
- aircraft support facilities,
- intermodal connections,
- land use planning, and
- summary.

9.1 CITY CENTER, GROUND LEVEL - UNION TERMINAL, CINCINNATI, OHIO

The site plan for the Union Terminal is presented in figure 34. As discussed in section 3.0, Union Terminal is located at the west end of an area that is considered to be one of the most celebrated art deco buildings in the country. Consequently, this site is extremely sensitive to any kind of development. The entrance to the Union Terminal from I-75 consists of a north and south parking area on either side of a tree-lined median. Entrance and exit roads are located between the median and auto parking areas.

9.1.1 Airfield Facilities Provided/Operational Capacity

9.1.1.1 Takeoff and Landing Area Facilities

The fact that the building configuration is long and narrow significantly limits options in terms of facility layout. It is difficult even to design a facility in accordance with minimum FAA requirements discussed in section 4.0, namely a 250 foot wide FATO.

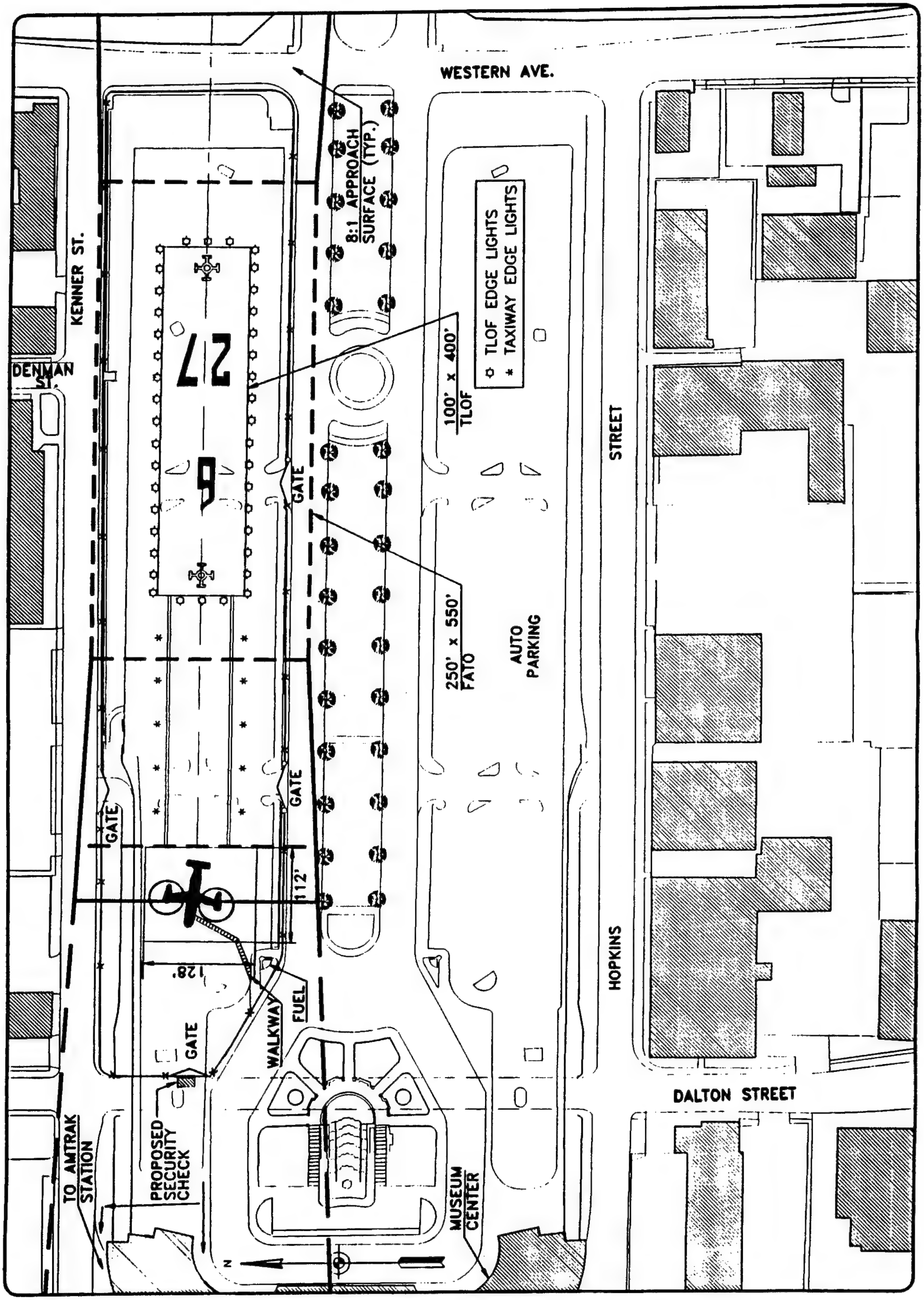


FIGURE 34 SITE PLAN - UNION TERMINAL, CINCINNATI, OHIO

The minimum sized FATO extends to Kenner Street and over the entrance and exit roads to Union Terminal. Curbing for the parking lot, light poles on either side of the parking lot, and the entrance to Union Terminal would all be considered obstructions to a 250 foot wide visual approach FATO. These obstructions would have an even greater impact on the more demanding non-precision and precision instrument FATO and imaginary surfaces. Therefore, only visual approaches can be planned for this site. There is a 550 foot long FATO from the center of TLOF 9 and a 670 foot long FATO from the center of TLOF 27 that is paved, clear, and could accommodate Part 29 RTO requirements. The FATO extends beneath the approach surfaces to the TLOFs.

9.1.1.2 Aircraft Parking Facilities

If an elongated TLOF is provided (figure 34), the site allows room for only one CTR parking position which is located west of the TLOF/FATO. Minimum CTR-22C parking dimensions, 175 feet square, preclude additional CTR parking positions at this site. The CTR parking position is located adjacent to the terminal to minimize passenger walking distance, and is marked and lighted. Operations at this site are seriously constrained, due to the single gate position, and the TLOF is under utilized.

Section 4.3.4 recommends at least two CTR parking positions for several reasons. If only one gate is available, then reliable scheduled operations are probably not possible. If a scheduled-CTR departure is delayed then an arriving CTR may not be able to land. If it does land, it will have to takeoff to allow departure of the delayed CTR. If a CTR encounters a serious maintenance problem, scheduled service may not be possible at this facility. The enplanement or deplanement of passengers on the TLOF or taxiway is not a desirable situation and could not be justified at a public-use facility.

The effects of rotorwash are expected to be more pronounced from hovering CTRs than from ground taxiing. Therefore, approaches to TLOF 9 or takeoffs from TLOF 27 should not be executed unless all personnel, particularly passengers or observers, are clear of the CTR gate position. Overflights of the populated gate area are also not desirable simply from a safety perspective. Vertiport design tradeoffs due to the effects of rotorwash need to be considered. These tradeoffs involve the consideration of safety, capacity, and land requirements (gate separations). (See section 4.3.3 for full discussion.)

An alternative layout, as presented in figure 35, permits additional gate positions at the expense of the elongated TLOF. Pedestrian walkways, that could also be served by a moving sidewalk or other electromechanical conveyance system, could be provided between the terminal and each gate position. The drawback to this vertiport configuration is that no room is provided on the TLOF for acceleration prior to liftoff. Vertical takeoff and departure will probably result in a reduced CTR takeoff weight in order to meet Category A requirements. This could preclude the use of this vertiport for scheduled services.

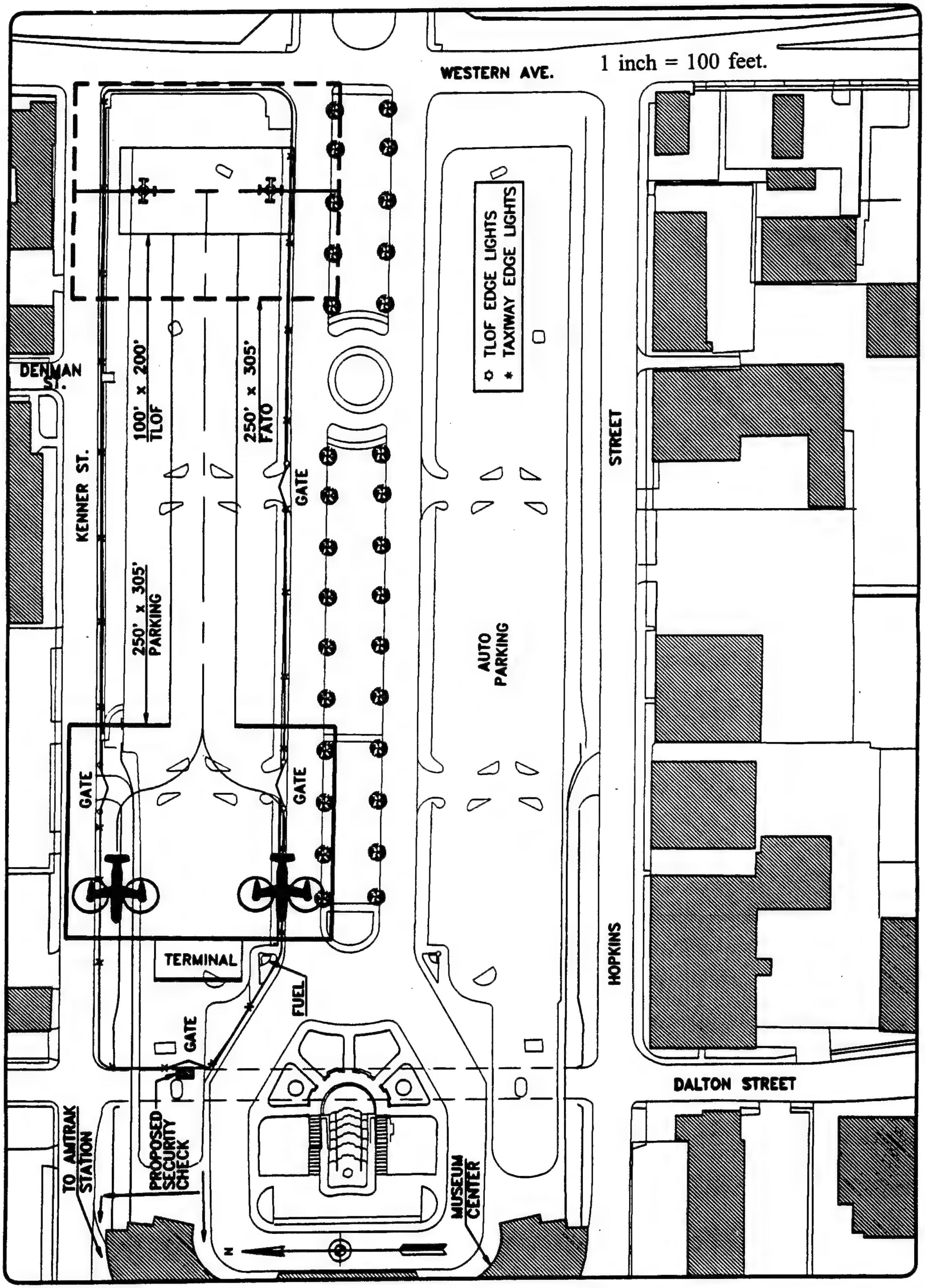


FIGURE 35 SITE PLAN ALTERNATIVE - UNION TERMINAL, CINCINNATI, OH

9.1.1.3 Taxiways

A taxiway is recommended between the FATO and the CTR parking position on the west side. It would be positioned and sized to accommodate both hover and ground taxi. However, due to size constraints, an aircraft parked on the taxiway would have to clear the taxiway and depart the vertiport before an aircraft at the parking position could depart.

There is insufficient room to accommodate a taxiway the length of the facility beside a TLOF or parking position. There is only enough room for either a taxiway or a TLOF, but not both. The designation of individual parking positions/TLOFs along the length of the facility would eliminate the need for a taxiway, thereby providing more space for parking. An alternative would be to develop a "jetway" for loading and unloading passengers.

If an elongated TLOF were planned for the site, it would significantly decrease the space available for aircraft parking, and therefore operational capacity. The benefits of a rollway or elongated TLOF were discussed in section 4.2.2. A 100 foot wide, 400 foot long TLOF and accompanying 250 foot wide by 550 foot long FATO are depicted in figure 34. A 400 foot rollway, however, would not accommodate 14 CFR Part 29 Category A rejected takeoff (RTO) requirements if the area needed to meet these requirements is measured from the center of the TLOF. Further research is required to determine accurate RTO requirements.

9.1.1.4 Pavement

Pavement design requirements were discussed in section 4.2.6. Movement areas (TLOF, taxiway, and parking positions) should be paved with PCC (rigid pavement) rather than flexible bituminous concrete in order to support the dynamic loads of the CTR as well as to minimize temperature related problems due to engine exhaust. The creation of substantial levels of engine exhaust and rotorwash would be minimized by the rollway, because the CTR would be able to operate in the STOL (airplane) mode rather than VTOL (helicopter) mode. Also, CTR hover taxiing is not required due to the paved access between the TLOF and CTR parking position.

9.1.1.5 Marking and Lighting

An elongated TLOF has the same markings as an airport runway in terms of magnetic direction (e.g., TLOF 9, TLOF 27, etc). The TLOF is marked as a visual vertiport. Lighting is limited to medium intensity TLOF and FATO perimeter lighting. Since the vertiport design will only accommodate visual operations, HILS and HALS are not required. Precision approach path indicators (PAPIs) are installed for the TLOF 9 and the TLOF 27 approaches. Taxiways and CTR parking positions are marked and lighted in accordance with FAA AC 150/5390-3.

9.1.1.6 Peak Hour - Annual Capacity

As discussed in section 4.1.2, the annual capacity of a single TLOF facility is estimated to be 32,760 operations. One TLOF could have an hourly capacity of nine operations, assuming a suitable number of CTR parking positions (section 4.3.4). Since the one CTR parking position accommodates only 2.6 operations per hour, the capacity of the vertiport would be limited to the lower number. The lack of an instrument approach would also restrict capacity since the facility would be closed during bad weather.

Using the alternative layout configuration with multiple parking positions/TLOFs (figure 35), operational capacity could be increased. However, as noted previously, such a layout would not allow any acceleration areas, which would significantly decrease the aircraft's takeoff weight, and therefore limit its payload.

9.1.2 V/STOL Performance Characteristics

9.1.2.1 VFR/IFR Procedures

Using an elongated TLOF, VFR procedures at the vertiport could entail either straight-in/straight-out flight tracks, or curved north-south tracks generally over I-75 to the east or the Ohio River to the west. Procedures would have to be developed to provide a specific visual approach track prior to reaching the FATO.

An instrument approach to a point-in-space with a visual approach to the FATO was considered. A north or south approach over I-75 to the extended FATO 27 centerline would not be possible because it would require a 1,200 foot straight segment prior to the edge of FATO (reference 8), and physical obstacles preclude this segment. A point-in-space approach to FATO 27 from the east of I-75 is not possible due to tall buildings and antennas, which are likely to be obstructions. An instrument approach to a point-in-space for a FATO 27 approach may be possible from the west because there are fewer tall buildings and antennas west of the city. To do this, a suitable final approach fix using a very high frequency omni-directional range (VOR), a non-directional beacon (NDB), distance measuring equipment (DME), or a dGPS waypoint (see section 1.1.2), would have to be established. However, at this time, only visual approach procedures are assumed practical for this site.

9.1.2.2 Air Traffic Control Issues

Cincinnati Approach Control would be the facility to provide ATC (arrival/departure/local) services for the vertiport. A control tower at the vertiport is not recommended due to the anticipated low demand. It is not expected to meet FAA operational thresholds for installation of a control tower. Private towers can be contracted by the facility sponsor to provide the same services as an FAA facility, although the cost would have to be absorbed by the facility sponsor. On the other hand, a universal communication radio (UNICOM) at the vertiport could provide advisories of activity on the vertiport surface and in the vicinity.

9.1.2.3 Airside Security and Emergency Access

A security fence surrounds the FATO and CTR parking position isolating CTR movement areas from auto parking, terminal, and roadway areas. A painted walkway would guide passengers from the CTR to Union Terminal for processing. Emergency response to the vertiport is made via any of the gates in the fence. A waiver of FAA FATO and transitional area obstruction-free criteria would have to be obtained, because some sections of the security fence would be located within the FATO.

9.1.2.4 Aircraft Separation Standards

Rotorwash (also referred to as wake turbulence once the aircraft is airborne) should not be an issue for departures or arrival, particularly if individual parking positions/TLOFs are used. Such a configuration would require direct climb operations, which would minimize the impact of rotorwash. With an elongated TLOF, however, rotorwash on takeoff for FATO 9 departures may affect aircraft, equipment, and personnel at the CTR parking position. If a CTR is at the parking position, a FATO 9 departure could be executed vertically, which would decrease the rotorwash on takeoff effect, but at a possible cost of decreased payload and/or range.

9.1.3 Terminal Building Requirements

9.1.3.1 Aircraft Gates

Under either conceptual layout scenario (figures 34 and 35), the width of the facility precludes the development of more than one gate at the terminal building. Since only one CTR parking position is possible with an elongated TLOF configuration, there is only one gate with this layout as well. Passengers deplane from the CTR at the parking position in front of the terminal and walk to the passenger terminal. If multiple parking positions/TLOFs are provided, pedestrian access can be provided between the gate and each parking position, although the single gate will act as a bottle neck during peak periods.

9.1.3.2 Passenger Handling Facilities and Security

Passengers are transferred in and out of the CTR at the designated parking position clear of the TLOF and taxiway. Transfer of passengers in and out of the aircraft even on a low-activity runway is a potential safety risk.

The existing AMTRAK railroad station at the west side of Union Terminal provides all terminal functions for CTR passengers. Areas in the AMTRAK station or in Union Terminal provide the necessary lobby/waiting areas. A terminal in the parking lot is not proposed, as it would affect the aesthetics of the site.

Security in the AMTRAK lobby/waiting areas is not proposed since separating vertiport/heliport passengers from all others passing through the Amtrak station will be very

difficult. Therefore, an enclosed security checkpoint is located just outside the fence gate along the painted walkway.

9.1.3.3 Airline Ticket Offices (ATO)

Airline ticket office (ATO) facilities (counter space and administrative/operations offices) are assumed to be located in the AMTRAK station as are other terminal functions. The floor plan of the AMTRAK station was not reviewed for the availability of floor space.

9.1.3.4 Cargo/Baggage Handling

Cargo and baggage is transported between the CTR parking position and the AMTRAK station. Deplaned cargo and baggage may be loaded directly onto trucks in the parking lot. Enplaned cargo is checked in at the AMTRAK station and transported to the CTR parking position via the same method as passengers. As an alternative, enplaned cargo could be checked in at the enclosed security check point described in section 9.1.3.2.

9.1.3.5 Automobile Parking/Rental Car/Access Road

Automobile parking lots are located at the south parking lot. Rental car kiosks could also be located in the south parking lot, with rental car administration areas in the AMTRAK station or Union Terminal. Access is via the entrance and exit roads to Union Terminal and the south parking lot.

9.1.4 Aircraft Support Facilities

9.1.4.1 Maintenance Area

There is not sufficient area at the Cincinnati site to accommodate maintenance hangars. Any emergency maintenance would have to be performed at the parking position which would limit the amount of maintenance that could be accomplished. One advantage of a multiple parking position/TLOF configuration is that an aircraft maintenance problem at one position will not prevent aircraft operations at the other positions, thereby effectively keeping the facility open. As a design principle, it is highly preferable to avoid the possibility that a single aircraft malfunction would close the facility.

9.1.4.2 Fueling Facilities

One fuel tank of approximately 10,000 gallons is located at a corner of the CTR parking position. A hose reel arrangement allows fueling without fuel trucks. The fuel system would have to be installed in accordance with NFPA and City of Cincinnati codes.

9.1.4.3 Aircraft Rescue and Firefighting (ARFF)

Access to the vertiport for ARFF vehicles and personnel is through any of the gates in the perimeter fence. ARFF equipment and agents described in section 7.3 are stored and staged inside the gate northeast of the CTR parking position.

9.1.4.4 De-Icing Equipment

Snow and ice at the vertiport is removed by mechanical means (plows, shovels, brooms, etc.). See section 7.5.1 for discussion on additional de-icing equipment. Aircraft de-icing capability, such as glycol, should also be provided. The use of a truck would greatly ease dispensing glycol to multiple parking positions and possibly eliminate the need to store glycol on the facility.

9.1.4.5 Automated Surface Observation System (ASOS)

An ASOS is recommended for this vertiport site following the rationale discussed in section 7.5.2.

9.1.5 Intermodal Connections

Rail, bus and taxi service, and auto parking are currently available at the site. Vertiport users would be able to use these facilities as well. Though possible, it is unlikely there would be any significant transfer of passengers between the air mode and the rail mode.

9.1.6 Land Use

9.1.6.1 Noise Footprint

Another extremely critical issue is the need to provide enough land for noise mitigation, particularly in residential areas. Noise impact may be the most important factor in public acceptance of CTR transportation. The present estimates of noise impact would require as much as 120 acres of noise compatible land around the facility to encompass the L_{dn} 65 dB noise contour. It is now anticipated that future aircraft designs may reduce noise impact on communities. However, although the exact amount of land would vary from site to site, planners need to be aware of the potential real estate requirements.

9.1.6.2 Vertiport Land Area

The part of the vertiport within the security fence encompasses 5.4 acres. The total vertiport area encompasses existing auto parking areas and terminal areas. However, since these areas presently exist and would not be for the exclusive use of vertiport users, they are not included in the vertiport area calculations.

9.1.6.3 Impact on Land Use

Except for the Union Terminal facility itself, a vertiport as proposed would not significantly affect land uses in the vicinity. Arrival and departure routes would be oriented along I-75 to the east and the Ohio River to the west. The close-in segments of TLOF 27 approach/TLOF 9 departure would be over commercial/office buildings and TLOF 9 departure/TLOF 27 arrival over less populated areas in the west section of the city. It is recommended that zoning be adopted to protect the imaginary surfaces of the vertiport.

9.1.7 Summary - Union Terminal, Cincinnati, Ohio

The previous paragraphs discuss the measures that would have to be taken to locate a vertiport at Cincinnati's Union Terminal. The feasibility of locating a vertiport at Union Terminal principally depends on waiver of obstruction requirements (vehicles on Kenner Street, the entrance road to Union Terminal, and trees on the entrance median) and on public acceptance. If such waivers are not possible, the entrance to Union Terminal would have to be substantially altered. Vehicles would not be able to use the entrance road; the trees along the north side of the median, and possibly on the south side as well, would have to be removed; and the section of Kenner Street north of the FATO would not be open to vehicular traffic.

For the variety of reasons discussed above, this is a very poor site for a public-use vertiport. The inability of the site to support instrument operations is a serious and probably fatal flaw. This is also a very poor site for a private-use vertiport. Any vertiport or large heliport would have an adverse impact on the aesthetics of the historic Union Terminal and would be unlikely to receive approval at the local level. Even if approval could be obtained, the facility would start its existence with serious community relations problems that would limit its probability for success.

9.2 CITY CENTER, ELEVATED - GREYHOUND PARKING GARAGE, PHOENIX, ARIZONA

The site plan for the vertiport at the Greyhound Parking Garage is shown on figure 36. The Greyhound Parking Garage in Phoenix, Arizona was selected, because it had been identified as the preferable heliport site in the 1986 "Heliport Needs Study for Phoenix, Arizona." The close-in commercial and light industrial uses surrounding the Greyhound Parking Garage are not noise sensitive.

As discussed in section 3.1.2, it is planned that the existing Greyhound building will eventually be demolished and a new structure, incorporating a multi-level parking garage, will be constructed in its place and the vertiport would be built on the new structure. The city will not allow that structure to impact use of 5th, 6th, Washington, or Jefferson Streets. Therefore, this proposed design incorporates the necessary vehicle ramps for the parking garage without affecting the use of Jefferson Street.

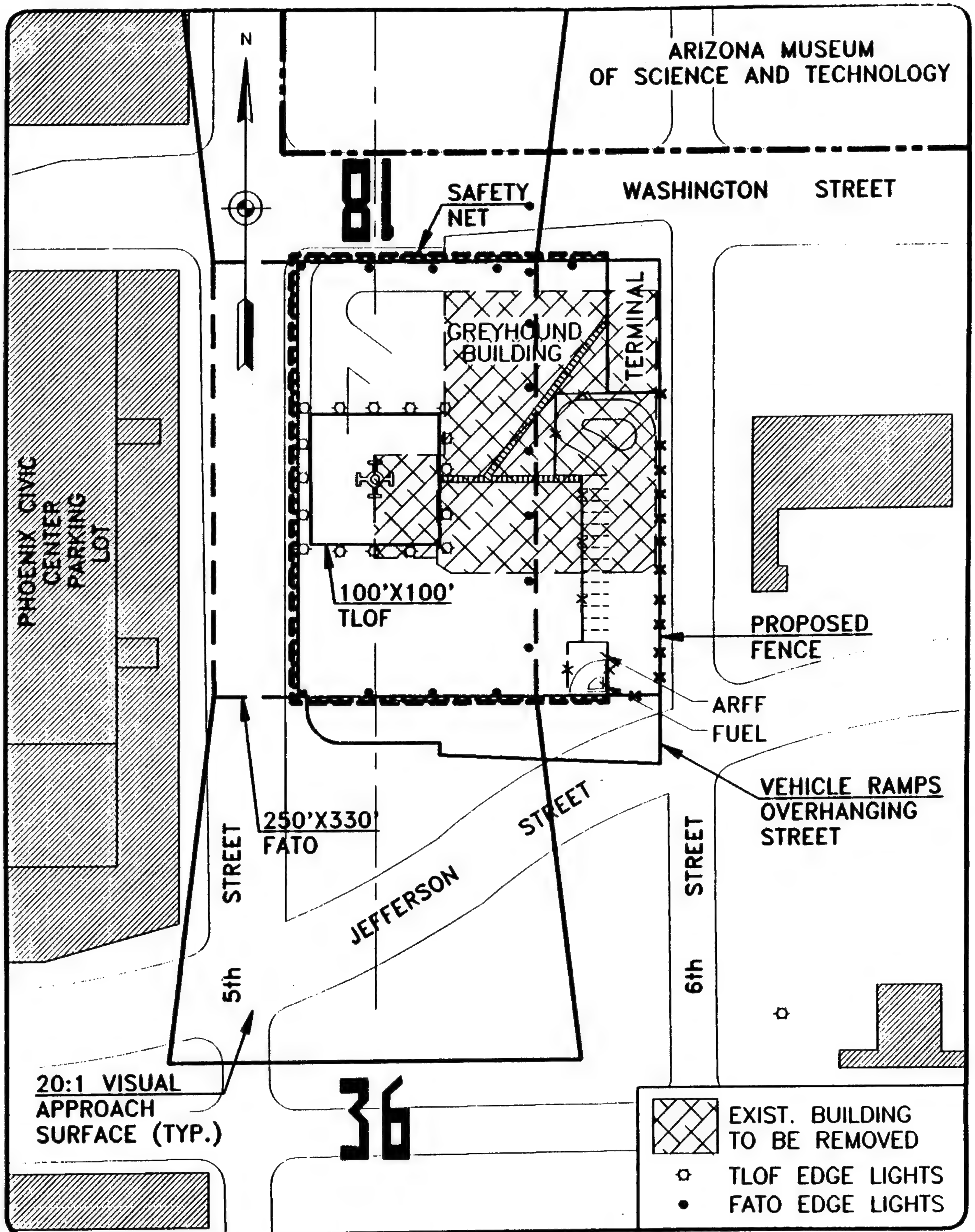


FIGURE 36 SITE PLAN - GREYHOUND PARKING GARAGE, PHOENIX, ARIZONA

9.2.1 Airfield Facilities Provided/Operational Capacity

9.2.1.1 Takeoff And Landing Area Facilities

At this site, there is room for only one 100 foot by 100 foot TLOF. Approaches can be made from either north or south, meaning that the TLOF can be considered either TLOF 36 or 18. The FATO has to extend over the edge of the structure to provide maximum distances for the CTR to accelerate once it has lifted off the TLOF.

There is not sufficient area on the structure for both a TLOF and a CTR parking position; the parking position would be considered co-located with the TLOF (section 9.2.1.2). Due to this constraint, the idea of an elongated TLOF was dropped from further consideration and replaced with a square, 100 foot by 100 foot TLOF. The square TLOF will be used for landings and takeoffs, as well as enplaning and deplaning passengers.

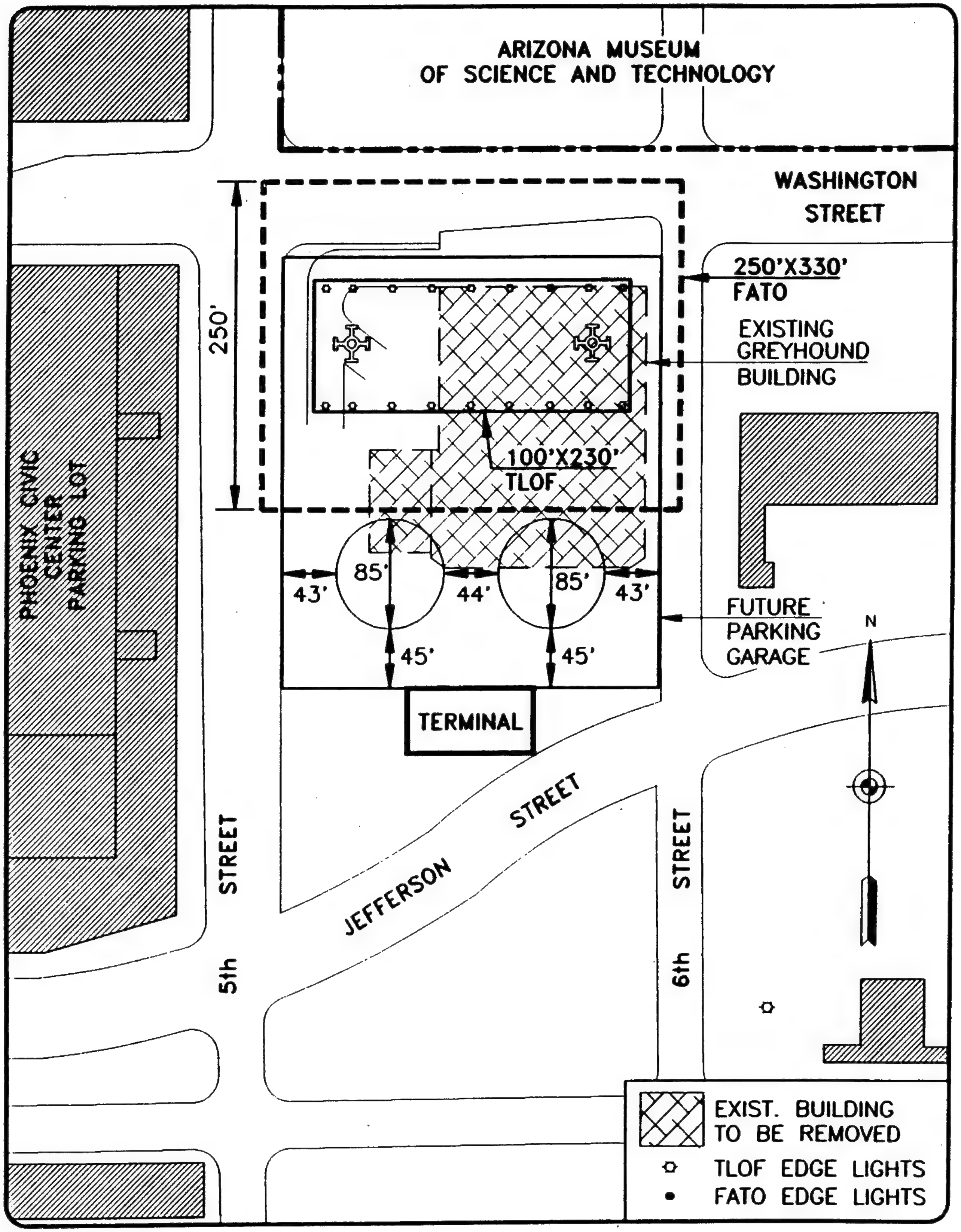
Due to the minimal area for acceleration, the CTR would be operated in the VTOL mode rather than the STOL mode. The Phoenix area is at an elevation of 1,132 MSL and has periods of extremely high temperatures. The combination of high vertiport elevation, high temperatures, and the minimal area for acceleration requires the CTR to be operated at potentially much less than maximum capability resulting in a significant reduction in range and/or payload.

A 5 foot wide safety net is constructed at the north, west, and south edges of the parking garage. A fence is constructed along the east side of the structure, south of the terminal building. In addition, a vehicle access ramp will be provided to the roof to allow for fuel trucks and emergency equipment. An approximately 40 foot wide area to the side of the FATO is available for additional facilities (see section 9.2.1.4.), assuming the transitional surfaces are free of obstructions. An alternative would be to develop a "jetway" for loading and unloading passengers.

An alternative site plan is shown in figure 37. The primary feature of this plan is to locate the terminal building services on one of the lower floors. This would allow a 100 by 230 foot TLOF and two parking spaces. The longer TLOF would provide a rollway so that CTRs would be able to have a greater acceleration distance and could therefore be operated at slightly greater range and/or payload. It would also provide greater safety to passengers because they would be on a lower floor during operations.

9.2.1.2 Aircraft Parking Facilities

One CTR gate position is essentially co-located with the TLOF (see section 9.4.1.1) because the minimum dimensions for a CTR-22C gate position are 175 feet square. However, this limitation may have limited application because there is no room for an adjacent CTR gate position. Passenger loading could be conducted closer to the terminal if a small helicopter needed access to the TLOF during loading/unloading operations. In summary, this vertiport has many of the same limitations that are discussed for the Union



1 inch = 100 feet

FIGURE 37 SITE PLAN ALTERNATIVE - GREYHOUND PARKING GARAGE, PHOENIX, ARIZONA

Terminal vertiport (section 9.1.1.2). Therefore, this vertiport configuration is too small to provide reliable scheduled CTR operations.

9.2.1.3 Taxiways

There be no requirement for hover taxiing, as there is no separate CTR parking position. However, the increased effects of heat exhaust and rotorwash during takeoff and landing will require the rooftop to be stressed for aircraft movement (also see pavement requirements section 9.2.1.4) and all passengers to be inside the terminal building before the CTR lands or takes off.

9.2.1.4 Pavement

Pavement design was discussed in section 4.2.6. Movement areas (TLOF, parking position, and fueling area) should be paved with rigid PCC rather than flexible bituminous concrete to support the dynamic loads of the CTR, as well as to minimize effects of engine exhaust and rotorwash as the CTR would be operated mostly in a VTOL mode.

Also, in the summer heat, bituminous pavement becomes soft and becomes rutted and sticky. Although in Phoenix, CTR taxiing is not required, there will be significant engine exhaust and rotorwash from the CTR engines on departure and arrival.

The rooftop surface should be constructed of concrete to minimize effects of engine exhaust and rotorwash. The effects of engine exhaust may also be of concern during use of the terminal building and other adjacent areas.

9.2.1.5 Marking and Lighting

The TLOF and FATO are marked in accordance with the FAA design AC for vertiports. With no instrument approaches to the FATO, HILS and HALS would not be required. The FATO and TLOF are lighted with medium intensity perimeter lights in accordance with FAA ACs. PAPI lights are provided for TLOF 18 and TLOF 36 approaches.

9.2.1.6 Peak Hour - Annual Capacity

It is assumed that each CTR flight will occupy the TLOF for 6 minutes (4.1.1), and a CTR gate will be occupied for approximately 32 minutes per flight (or 16 minutes per operation). This is based on 30 minutes at the gate plus 5 percent (2 minutes) for inefficiency per flight, for a total of 32 minutes. This equates to approximately 16 minutes for deplaning and 16 minutes for enplaning.

Since the CTR parking position is not separate from the TLOF, this TLOF would be occupied for six minutes plus 16 minutes for a total of 22 minutes per operation. This in turn equates to a vertiport capacity of 3 operations per hour.

The capacity and efficiency of the Phoenix vertiport is hindered by a number of factors:

- the minimal area for acceleration requires a longer time for a departing CTR to clear the TLOF;
- since the TLOF and the CTR parking area are co-located, the TLOF is occupied while passengers are enplaning and deplaning;
- any mechanical problem with the CTR requires the vertiport to be closed to all traffic until the CTR is repaired, departs, and is clear of the FATO; and
- if an instrument approach would not be commissioned, the vertiport would be closed during bad weather, thereby restricting annual capacity.

9.2.2 V/STOL Performance Characteristics

9.2.2.1 VFR/IFR Procedures

There is sufficient area around the vertiport to allow straight-in/straight-out approaches or departures, as well as standard traffic patterns. One benefit of the CTR is its potential ability to execute steep approaches and departures. Steep straight-in/straight-out approaches or departures are recommended to minimize exposure to noise. (Boeing Helicopters analysis has indicated that the CTR noise footprint is minimized if the approach is segmented with the angle of the final segment being in the range of 9 to 12 degrees.) Any requirement for curved approaches depends on ATC considerations and should be coordinated with approach control at Phoenix Sky Harbor International Airport.

The approach surfaces are aligned in a north-south direction to avoid flights over buildings close to, and east and west of, the Greyhound building. Visual approaches to the vertiport require smaller FATOs, TLOFs, and less critical transitional surfaces than nonprecision instrument approaches, thereby allowing development of additional facilities with imaginary surfaces being free of obstructions.

Even assuming the terminal building is no more than 15 feet high, it would obstruct a transitional surface by 8 to 10 feet. Nonprecision instrument approach procedure would not be feasible. In addition, a precision instrument approach would not be possible, because there is not sufficient area on the rooftop north and south of the FATO to accommodate approach lights.

An alternative to direct IFR approaches is a nonprecision instrument approach to a point-in-space, with the remainder of the approach being a visual approach to TLOF 18 or TLOF 36.

Due to these circumstances, the layout of the Phoenix site has been designed assuming visual approaches to the TLOF with point-in-space, nonprecision instrument approaches

from the north and the south. A suitable final approach fix will be required for TLOF 18 and TLOF 36 approaches and could include intersecting radials from two VORs, an NDB, or dGPS waypoint, as discussed in section 1.1.2.

Since there are no buildings immediately north or south of the Phoenix vertiport, FAR Part 29 Category A OEI requirements could be accommodated, however, not with the standard vertical takeoff profile. A suitable surface area can be made available for RTOs if the pilot executes a vertical takeoff while climbing backwards to the CDP. After the backward climb, the pilot would takeoff in a forward direction over the TLOF.

9.2.2.2 ATC Issues

ATC at the Phoenix Sky Harbor International Airport would be expected to provide arrival/departure/local control services for the vertiport. A control tower is not required at the vertiport due to its limited capacity. A UNICOM would advise pilots of activity on the vertiport and in the vertiport area.

9.2.2.3 Airside Security and Emergency Access

The operational area will be kept secure by restricting persons who have not passed through security at the terminal outside of the CTR movement area.

9.2.2.4 Aircraft Separation Standards

Rotorwash should not be an issue at the Phoenix vertiport due to the fact that arrivals and departures would be aligned away from the parking position, and CTRs at the vertiport would always be operated in the VTOL mode due to the limited acceleration area.

9.2.3 Terminal Building Requirements

9.2.3.1 Aircraft Gates

Since there is limited capacity and space on the roof, only one gate position is provided. Passengers would walk between the CTR and the terminal via a striped walkway.

9.2.3.2 Passenger Handling Facilities

A terminal building of up to 4,000 square feet could be located at the northeast corner of the vertiport (figure 36), or it could be located on the floor below the roof to allow more space for operational capacity on the roof (figure 37). The Phoenix terminal can be of sufficient size to accommodate baggage claim, ticketing, lobby and other passenger handling functions. The security fence, discussed above, is constructed to allow passengers to exit, but not enter the movement area. Security screening facilities are located in the terminal building.

An elevator and stairs are provided even though auto parking is provided at the vertiport. Elevator access to the vertiport level is through the terminal building. It is recommended that no passengers be allowed to enter the movement area without first passing through the security screening in the terminal building. In this manner, all persons entering the movement area are cleared through security. To increase efficiency, deplaning passengers are allowed to exit the movement area through the terminal building or proceed from the CTR directly to the parking lot through the gate.

9.2.3.3 Airline Ticket Offices (ATO)

The terminal is of sufficient size to accommodate airline ticket offices. Equipment and some storage may have to be located on a lower level of the parking garage immediately beneath the heliport/vertiport.

9.2.3.4 Cargo/Baggage Handling

As with enplaning passengers, cargo and baggage is processed through the terminal building. Deplaned baggage is processed through the terminal as well. Deplaning passengers are able to take their carry-on baggage from the CTR themselves, either through the terminal or directly to the parking lot.

9.2.3.5 Automobile Parking/Rental Car/Access Road

Automobile parking is available at all levels of the parking garage, with access to the vertiport via the elevator. Parking on the vertiport (approximately 14 spaces) should be reserved for passenger meeters and greeters, and not for passengers themselves. Vehicles should not be parked at the vertiport parking lot for any more time than is required to discharge or pick up passengers.

An area for rental car offices related to passenger services is available inside the terminal. Rental car ready lots and drop-off lots are on a lower level of the parking garage. The rental car company has to provide staff on the level where the ready lot and drop-off lot are located.

Access to the vertiport is via the entrance ramps of the parking garage. The cul-de-sac is used only for vehicle standing (the driver remains with the vehicle) to drop off departing passengers quickly.

9.2.4 Aircraft Support Facilities

9.2.4.1 Maintenance Area

There is not sufficient area on the vertiport for CTR maintenance areas, aprons, or hangars. If maintenance is required on a CTR at the vertiport, the vertiport would be closed to all traffic until the CTR was repaired and had departed the TLOF.

9.2.4.2 Fueling Facilities

One fuel tank of approximately 10,000 gallons with hydrant fueling may be located at the vertiport, depending on local fire codes. If local fire codes do not permit a fuel storage tank at the parking garage, a fuel truck may be used. The fuel truck would have to be refueled at the Phoenix Sky Harbor International Airport or at the nearest bulk storage facility for aviation fuel. This technique requires more frequent trips by a fuel truck traveling through the parking garage than with a storage tank at the vertiport. In general, building and fire codes would not preclude fuel trucks from driving through a parking garage on its way to a rooftop facility, although individual municipalities may impose some restrictions on that type of access.

An alternative is an above-ground storage tank at ground level with the fuel pumped to the vertiport surface to be dispensed to the aircraft by hydrant.

9.2.4.3 Aircraft Rescue and Firefighting (ARFF)

Access to the vertiport for ARFF vehicles and personnel is via the parking garage. Fire protection required for rooftop heliports by NFPA 418 would be provided by storing agents and equipment on the level of the parking garage immediately below the vertiport.

An alternative is to store firefighting agents and equipment in the south end of the vertiport auto parking area, next to the fueling area. The latter is not recommended as it decreases the number of parking spaces and occupies space on a constrained rooftop which is better utilized for other purposes. Vehicle access ramps need to be provided to the rooftop for emergency vehicles, as well as the fuel trucks.

9.2.4.4 De-icing Equipment

De-icing equipment is not required at the Phoenix vertiport due to the climatic conditions of the area.

9.2.4.5 Automated Surface Observation System (ASOS)

An ASOS is recommended at the vertiport, following the rationale in section 7.5.2.

9.2.5 Intermodal Connections

Taxis can be requested through phones at the vertiport. Metro bus service is available at the civic center across the street. Auto parking is available in the parking garage. Vertiport users are able to use these same facilities.

9.2.6 Land Use

9.2.6.1 Noise Footprint

Another extremely critical issue is the need to provide enough land for noise mitigation, particularly near residential areas. Noise impact may be the most important determinant in public acceptance of CTR transportation. The present estimates of noise impact would require as much as 120 acres of noise compatible land around the facility to encompass the L_{dn} 65 dB noise contour. It is anticipated that future aircraft designs may reduce noise impact on communities. However, although the exact amount of land would vary from site to site, planners need to be aware of the potential real estate requirements.

9.2.6.2 Vertiport Land Area

The Phoenix vertiport encompasses the top level of the parking garage, an area of 89,600 square feet (2.1 acres) as depicted. There are no noise-sensitive land uses in close proximity to the vertiport site.

9.2.6.3 Impact on Land Use

The north-south arrival and departure tracks serve to minimize impact to close-in buildings east and west of the parking garage. A vertiport on top of a parking garage is consistent with existing use of the structure (parking garage and bus terminal). There are no obstructions to approach or transitional surfaces, but zoning to protect those surfaces should be developed.

9.2.7 Summary - Greyhound Parking Garage, Phoenix, Arizona

A vertiport with a passenger terminal and auto parking could be located on top of a parking garage as depicted. A vertiport is not feasible on the existing structure, and the new structure would have to be constructed approximately as depicted. Elevator access to the vertiport level should be considered from the conceptual plans for construction of the parking structure. The feasibility of an instrument approach procedure to a point-in-space with final approaches under visual control is dependent on a suitable procedure being coordinated with the control facility for the Phoenix Sky Harbor International Airport.

For the variety of reasons discussed above, this is a poor site for a public-use vertiport. The limited area available for the FATO and the limited parking are both serious shortcomings. If instrument procedures cannot be commissioned, this would be a serious and probably fatal flaw. The limited area available for the FATO is probably a fatal flaw by itself.

9.3 METRO STATION - UNION STATION, WASHINGTON, D.C.

Union Station was discussed in the 1992 report, "Helicopter System Inventory And Vertiport Feasibility Study For Metropolitan Washington." The close-in areas around the site are mostly for general office use and are generally not noise sensitive except for a school located east of 2nd Street, 700 feet from Union Station. The vertiport site is on the four-level parking garage north of Union Station. As noted, a Metro light rail subway station is located underneath the building. The location is a working AMTRAK station. The railroad tracks to Union Station are to the east. The fourth level of the parking garage is currently used for auto parking. There are elevator, heating, ventilating, and air conditioning (HVAC), and other structures on top of the parking garage that cause significant obstructions to the FATO. Consequently, an additional level would have to be constructed to accommodate a vertiport. The site plan for the parking garage vertiport at Union Station is shown in figure 38.

9.3.1 Airfield Facilities Provided/Operational Capacity

9.3.1.1 Takeoff And Landing Area Facilities

Figure 38 reflects the assumption that a vertiport is constructed as an additional level on top of the parking garage. The space available allows one TLOF measuring 150 feet by 150 feet, and a 300 feet by 300 feet FATO. A nonprecision instrument approach and a visual approach are shown from the east using the compatible area of the railroad tracks for noise abatement (see section 9.3.2.1.). The transitional surface for the TLOF 29 (direction of visual approach) inclines from the edge of the FATO at a slope of 2:1, requiring a separation from the CTR parking position of 42 feet. The TLOF 20 is a nonprecision instrument approach. A 420 foot long rollway is possible but, if used, there would be no room available for an aircraft parking position or elevator access. The 150 foot by 150 foot TLOF allows two CTR parking positions, as well as elevator and stair access. There is no area available for CTR acceleration at the Union Station site. As a result, the CTR would be operated entirely in the VTOL rather than STOL mode for takeoffs and arrivals. Operating in the VTOL mode may require the CTR to operate at less than maximum gross weight capability resulting in reduced effective range and/or payload.

A 5-foot wide safety net would be constructed at the west, north, and east edges of the structure. The south side could be fenced as it is an enclosed elevator area. It also needs to be marked and lighted to avoid interference with aircraft operations.

There is not sufficient surface area to accommodate RTOs on the vertiport with the standard vertical takeoff profile. However, suitable surface area can be made available for RTOs if the pilot executes a vertical takeoff while climbing backwards to the CDP. As noted previously, however, pilots and passengers do not like using this procedure to meet Category A requirements. The pilot would takeoff in a forward direction over the TLOF. Since there are no buildings immediately north or east of the vertiport, FAR Part 29 Category A OEI requirements could be accommodated. FAR Part 29 Category A OEI

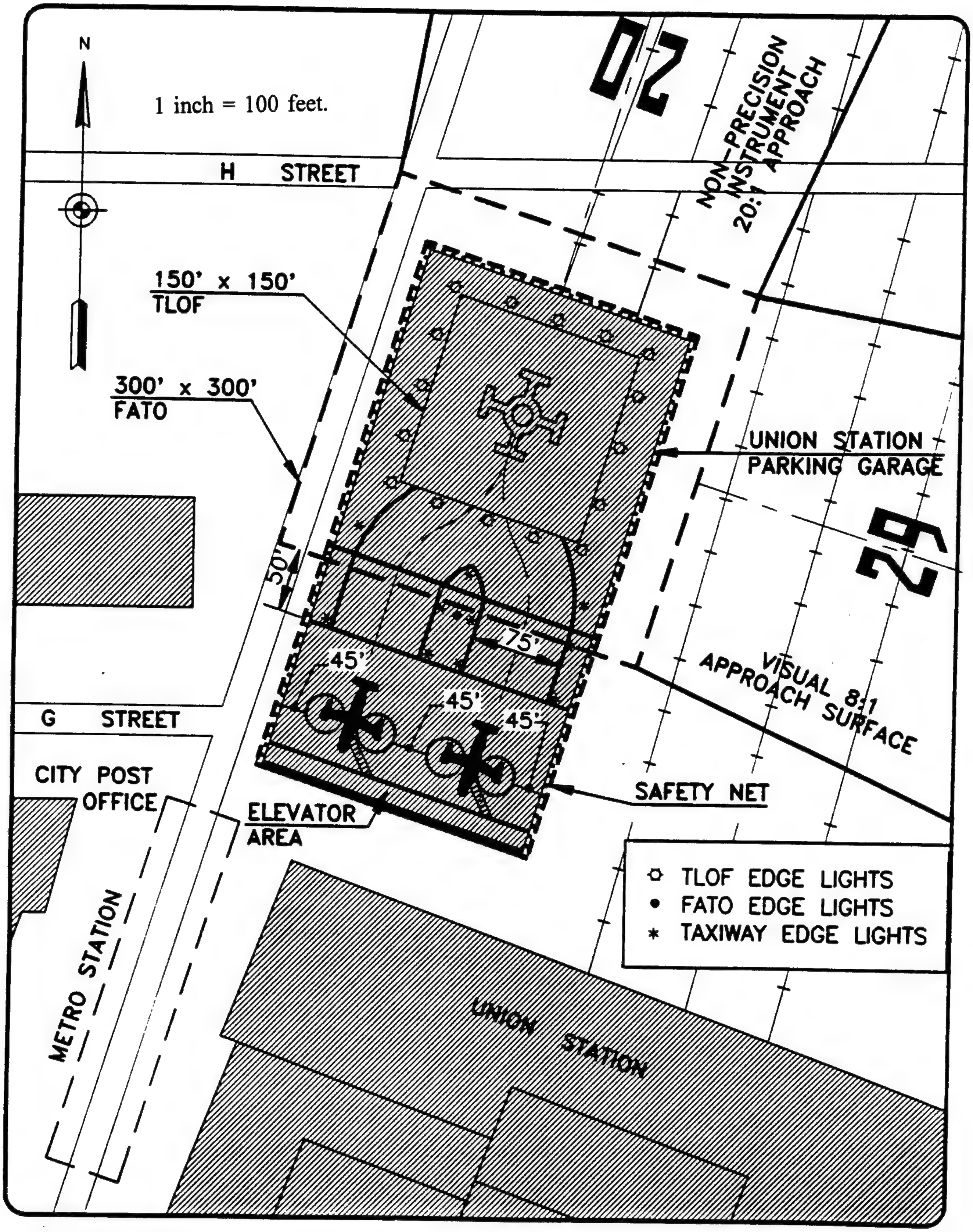


FIGURE 38 SITE PLAN - UNION STATION, WASHINGTON, D.C.

requirements could also be met by the pilot using the height of the vertiport above ground to recover airspeed after an OEI occurrence and to resume departure.

9.3.1.2 Aircraft Parking Facilities

Two CTR gate positions are located at the south end of the vertiport. Each of these positions is 175 feet square. Access to the gate positions is via two 75-foot wide taxiways. As noted, the gate positions are separated from the FATO by 50 feet. The gate positions are also located as close as possible to the elevator area to minimize walking distances.

The rotorwash effects should be minimal for this layout since operations can easily be halted whenever a CTR arrives or departs. Vertiport design tradeoffs due to the effects of rotorwash need to be considered. These tradeoffs involve the consideration of safety, capacity, and land requirements (gate separations). (See section 4.3.3 for full discussion.) The weakness to this vertiport configuration is the severe under utilization of TLOF capacity due to the small gate area. This TLOF also requires vertical takeoffs and landings that will reduce Category A performance.

9.3.1.3 Taxiways

The 75 foot wide taxiway would accommodate ground taxiing or hover taxiing. Rotorwash can be minimized by operating the CTRs in a ground taxi mode as much as possible. The TLOF and the CTR parking positions are separated by approximately 130 feet. This is not sufficient to protect passengers outside the CTR from rotorwash when CTRs are landing, departing, or taxiing at the vertiport. It is recommended that passengers be inside the CTR or inside the elevator structure (off the vertiport surface) before an additional CTR lands at, or departs from, the TLOF as a safety precaution. It is also possible that a small wall or barrier could be installed between the elevator and parked aircraft to deflect rotorwash from the elevators. An alternative would be to develop "jetways" for loading and unloading of passengers.

9.3.1.4 Pavement

Pavement design was discussed in section 4.2.6. Movement areas (TLOF, taxiway, and CTR parking positions) should be paved with rigid PCC rather than flexible bituminous concrete to support the dynamic loads of the CTR, as well as to minimize effects of engine exhaust and rotorwash as the CTR would be operated mostly in a VTOL mode. CTR hover taxiing is not required, since there is paved access between the TLOF and CTR parking positions.

As the CTR would be operated totally in the VTOL mode rather than the STOL mode, there is significant downward engine exhaust from the CTR engines during departure and arrival. Therefore, all of the rooftop surface should be constructed of portland cement concrete to minimize effects of the engine exhaust. The effects of engine exhaust is also of concern to the CTR parking positions.

9.3.1.5 Marking and Lighting

With no precision instrument approaches to the FATO, HILS and HALS are not required. The FATO and TLOF would be lighted with medium intensity perimeter lights in accordance with FAA ACs. PAPIs should be provided for the TLOF 20 and TLOF 29 approaches.

9.3.1.6 Peak Hour - Annual Capacity

As discussed previously, the capacity of one TLOF is assumed to be nine operations per hour if sufficient gates are available. However, each CTR gate has a capacity of approximately 2.6 operations per hour. Thus, the two parking positions provide an operational capacity of approximately five operations per hour.

The annual capacity of one TLOF is estimated to be 32,760 operations based on 9 operations per hour and adequate gates (section 4.3.4). At Union Station, hourly capacity is limited to the capacity of the two parking positions, 5.2 operations (takeoffs and landings) per hour.

9.3.2 V/STOL Performance Characteristics

9.3.2.1 VFR/IFR Procedures

There is sufficient area around the vertiport to allow straight-in/straight-out approaches or departures from TLOF 20 or 29. Any traffic patterns other than straight in or out are not recommended at the Union Station site because aircraft would fly in the proximity of key buildings such as the White House and the U.S. Capital, which are protected by prohibited area P-56.

A straight track to/from TLOF 20 routes traffic over the railroad tracks. A straight track to/from TLOF 29 allows aircraft to reach the vertiport while minimizing intrusions into P-56. A revision to P-56 would be required to allow operation of the vertiport.

There is not sufficient area on the rooftop for approach lights, so it is unlikely that a precision instrument approach could be installed. However, there is sufficient area to accommodate a non-precision instrument TLOF and FATO. A nonprecision instrument approach is proposed for TLOF 20, as the approach would be along railroad tracks, with minimal, if any, obstructions. A nonprecision instrument approach to TLOF 29 is not recommended, as the transition area is obstructed by the parked CTRs.

A suitable final approach fix is required for the TLOF 20 approach. A suitable final approach fix could include intersecting radials from two VORs, a marker beacon, or a global positioning system (GPS) waypoint.

9.3.2.2 ATC Issues

ATC services at the vertiport are expected to be provided by Washington Approach Control, the airport nearest Union Station. A control tower is not required at the vertiport due to the limited capacity of the vertiport. A UNICOM at the vertiport will advise pilots of activity on the vertiport and in the vertiport area.

9.3.2.3 Airside Security and Emergency Access

Security fences are not necessary because the vertiport is elevated. Entry would have to be monitored at the elevator and stair access points.

9.3.2.4 Aircraft Separation Standards

Wake turbulence should not be an issue at a Union Station vertiport due to the low capacity of the vertiport. Rotorwash on takeoff should not be a significant issue, as CTRs would be operated in a VTOL mode. CTRs operated in a VTOL mode require no special procedures other than caution relative to the effect of rotorwash during arrivals and departures. Hover taxiing should not be done at the vertiport to minimize the effects of engine exhaust and rotorwash, as suitable ground taxiing facilities are provided. Since the two taxiways at the vertiport are not parallel, one CTR should be at the parking position before the second CTR leaves the parking position for the TLOF or arrives at the TLOF and taxies to the second parking position.

9.3.3 Terminal Building Facilities

9.3.3.1 Aircraft Gates

The two CTR parking positions provide two potential gates if smaller rotorcraft are operated from the vertiport. Passengers would have to be grouped in the elevator area to ensure they use the correct gate. The CTR passengers would walk between CTR parking positions and the elevator area via a striped walkway.

9.3.3.2 Passenger Handling Facilities

There is not sufficient area on the upper level of the vertiport for passenger handling facilities. Such facilities have to be located in one of the lower areas of the parking garage or in Union Station. It is recommended that security screening devices be installed in the elevator area at the vertiport to ensure that passengers reaching the movement area have been checked through security. All passengers will have to be screened prior to exiting the elevator area. Screening could not be accomplished on a lower level of the parking garage unless a separate elevator or stairs serves the vertiport.

9.3.3.3 Airline Ticket Offices (ATO)

ATOs will have to be located in one of the lower areas of the parking garage or in Union Station as there is not sufficient area on the upper level of the vertiport for ATOs.

9.3.3.4 Cargo/Baggage Handling

Cargo/baggage handling facilities will have to be located in one of the lower areas of the garage or in Union Station. Carry-on and checked baggage would be processed through the same security facilities discussed in section 9.3.3.2.

9.3.3.5 Automobile Parking/Rental Car/Access Road

Adequate automobile parking is available in the structure. Rental car ready lots and return lots would be located in the parking garage. Rental car offices could be located in the parking garage or in Union Station. The access roads serving the parking garage does not have to be changed. The only method of access to the vertiport would be via the elevator.

9.3.4 Aircraft Support Facilities

9.3.4.1 Maintenance Area

There is not sufficient area at the vertiport to accommodate maintenance hangars or aprons. Any CTR maintenance done at the vertiport would have to be done at one of the CTR parking positions. Space at the Union Station vertiport allows a second CTR parking position to be used to provide an area for repairs on a CTR without closing the vertiport to operations.

9.3.4.2 Fueling Facilities

There is not sufficient area to locate a fueling hydrant at the vertiport, so on-vertiport fueling is not advocated.

9.3.4.3 Aircraft Rescue and Firefighting (ARFF)

Access to the vertiport for ARFF equipment and personnel is via the elevator or stairs. In addition, vehicle access ramps to the rooftop should be provided for emergency vehicles. Fire extinguishers, as described in section 7.3, would be stored at the southwest and southeast corners of the CTR parking area. There is not sufficient area on the vertiport level to store additional ARFF equipment and agents for rooftop heliports as required by NFPA 418 and as described in section 7.3. ARFF equipment and agents would be stored on the lower level of the parking garage and the ARFF agents would be pumped to hydrants located on the vertiport level.

9.3.4.4 De-Icing Equipment

Washington D.C. receives significant snow fall during winter months. Mechanical snow removal methods, as described in section 7.5.1, could be used. A pavement heating system, as described in section 7.5.1, could be considered as an alternative for snow and ice removal on the vertiport surface during winter months. In addition, an aircraft de-icing truck that dispenses glycol should also be available on the roof.

9.3.4.5 Automated Surface Observation System (ASOS)

An ASOS is recommended for the vertiport following the rationale discussed in section 7.5.2.

9.3.5 Intermodal Connections

Additional transportation facilities do not have to be constructed for the vertiport. Rail, subway, bus, and taxi service presently exist at Union Station and offer significant intermodal ridership potential.

9.3.6 Land Use

9.3.6.1 Noise Footprint

Another extremely critical issue is the need to provide enough land for noise mitigation, particularly in residential areas. Noise impact may be the most important determinant in public acceptance of CTR transportation. The present estimates of noise impact would require as much as 120 acres of noise compatible land around the facility to encompass the L_{dn} 65 dB noise contour. It is anticipated that future aircraft designs may reduce noise impact on communities. However, although the exact amount of land would vary from site to site, planners need to be aware of the potential real estate requirements.

9.3.6.2 Vertiport Land Area

Union Station vertiport would encompass an area of 92,400 square feet (2.1 acres). Not included in this area is the terminal building, auto parking, ARFF equipment storage, etc. that are located in the parking garage or Union Station.

9.3.6.3 Impact on Land Use

The prohibited area P-56 would have to be revised so that operation of the vertiport would be allowed. The TLOF 20 approach would be conducted over and along the railroad tracks. A junior high school is located east of 2nd Street, 700 feet from Union Station, and should be avoided. As the CTR would be operated in a VTOL mode, noise impacts may be experienced at the school. A noise abatement measure would include using the

TLOF 20 approach as much as possible and executing approaches as steep as practicable when conducting the TLOF 29 approach.

9.3.7 Summary - Union Station, Washington, D.C.

The items in the previous paragraphs note serious issues to be resolved to allow the location of a vertiport at Union Station. One critical issue to be resolved would involve a revision of prohibited area P-56 to allow CTR flights to and from Union Station. Historically, temporary waivers to fly within P-56 have been almost impossible to obtain.

A second critical issue to be resolved is the opposition from the community and many of their elected officials. Historically, this opposition has been formidable.

For the variety of reasons discussed in the preceding paragraphs, this site is less than ideal for a public-use vertiport. The limited area available for the FATO and the limited parking are both serious shortcomings.

9.4 SUBURBAN - NEW VERTIPORT, MANSFIELD, TEXAS

The first three sites that have been discussed are located in space-constrained urban areas or on rooftops. The Mansfield site was selected to present a suburban site that is not as space-constrained as the other sites. At approximately 180 acres, the Mansfield location is the largest of the sites discussed. Due to the suburban location, the site has the potential to accommodate the largest vertiport and the most activity. The site plan for a vertiport in Mansfield, Texas is shown on figure 39.

Because of its size and location, this site is capable of accommodating the most active facilities. This site is also able to provide fuel and maintenance services that would allow a number of smaller nearby urban vertiports to function more efficiently.

The Mansfield vertiport is flexible in accommodating growth, as the parking positions can be increased in number and size to accommodate larger aircraft. Also, the number of parking positions allow CTR repairs without affecting operation of the vertiport.

9.4.1 Airfield Facilities Provided/Operational Capacity

9.4.1.1 Takeoff and Landing Area Facilities

There is space available for two 150 foot wide by 850 foot long TLOFs with 300 foot wide by 1,000 foot long FATOs. These would be TLOF 5-23 and TLOF 14-32. The inner part of the approach surface that is up to 35 feet above the vertiport surface is within the heliport boundary. The TLOFs are positioned as depicted to allow maximum use of the land after the extension of Lone Star Road. Actual TLOF orientation, if the vertiport is built, may require somewhat different alignments to avoid nearby residential areas by using

several highways for approach/departure paths, but sufficient areas exist to accommodate changes as final zoning decisions are made.

An 850 foot long rollway is provided for each TLOF. The total length of the FATO (1,000 feet) is available for a rollway, as the FATO is at ground level and is able to provide ground effect for the CTRs. CTRs can be operated exclusively in the STOL mode at the Mansfield site as defined.

The length of the TLOFs is such that RTOs could be met within the TLOF. FAR Part 29 Category A OEI requirements, even given the high temperatures of the area, would be able to be met by the TLOF and FATO. The two TLOFs/FATOs are able to accommodate the CTR-22C at maximum gross weight.

9.4.1.2 Aircraft Parking Facilities

Six CTR gate positions are located near the terminal building in this vertiport design. While this number of gates is considered more than adequate, the size of the vertiport allows for future expansion. Additional gate positions are available to the west by shifting the location of the fuel farm, cargo area, and CTR hangers to locations further west. Each gate position is 175 square. These gate positions can also be increased in size to accommodate larger CTRs that might be developed in the future.

Rotorwash effects on takeoff and landing are minimal with this facility since the rollway is located 300 to 400 feet away from gate positions. All movement of CTRs at this facility should be accomplished by ground taxi. Vertiport design tradeoffs due to the effects of rotorwash need to be considered. These tradeoffs involve the consideration of safety, capacity, and land requirements (gate separations). (See section 4.3.3 for full discussion.)

9.4.1.3 Taxiways

A 75 foot wide parallel taxiway to both TLOF 5-23 and TLOF 14-32 is shown. The taxiway parallel to TLOF 5-23 is extended to serve the CTR parking positions, cargo area, and hangar area. Connector stub taxiways connect the parallel taxiway to the TLOF 5 and 32 ends. A connector stub also connects the intersection of the TLOF 23 and TLOF 14 ends with the northeast corner of the terminal apron.

This taxiway arrangement will allow each end of the TLOF to be reached without crossing or taxiing along the other TLOF. The centerline of the parallel taxiway is located 288 feet from the centerline of the TLOFs, as provided in design criteria. The 75 foot wide taxiway and 316 foot wide taxiway safety area allow CTRs to use the taxiways without affecting the TLOFs or the CTR parking positions. The parallel taxiways are paved, allowing ground taxiing rather than hover taxiing.

9.4.1.4 Pavement

Pavement design was discussed in section 4.2.6. Movement areas (TLOF, taxiway, and CTR parking positions) should be paved with rigid PCC rather than flexible bituminous concrete to support the dynamic loads of the CTR, as well as to minimize effects of engine exhaust and rotorwash as the CTR would be operated in a STOL mode. CTR hover taxiing is not required, as there is paved access between the TLOF and CTR parking position.

9.4.1.5 Marking and Lighting

TLOF 5-23 and TLOF 14-32 are marked with precision instrument markings. HALS is used for the TLOF 5 and TLOF 32 approaches. HILS would be installed for TLOF 5-23 and TLOF 14-32. PAPIs should be installed for TLOFs 5, 23, 14, and 32. Medium intensity taxiway edge lights (MITLs) would be used for the parallel taxiway.

9.4.1.6 Peak Hour - Annual Capacity

Using FAA AC 150/5360-5, the annual service volume of a two-runway airport configured like the vertiport in Mansfield would be 210,000 to 225,000 operations if operated like an airport. If hourly capacity were not constrained by the number of CTR parking positions, the annual capacity of the vertiport would be the capacity of the TLOFs, 210,000 to 225,000 operations.

As stated previously, it is assumed that each parking position or gate has a capacity of 2.6 operations per hour. Total gate capacity at the Mansfield site would then be 15.6 operations per hour (6 x 2.6). It was previously stated that each CTR operation would occupy the TLOF for an average of 6 minutes (4.1.1). Assuming an adequate number of parking positions or gates and assuming a parallel taxiway, each CTR operation would most likely occupy the TLOF for less than 6 minutes per operation, based on VFR hourly capacity from FAA AC 150/5060-5, "Airfield Capacity and Delay," or a one- and two-runway airport with radar coverage, a precision instrument approach, parallel taxiway, and no airspace constraints.

Studies have not been done on occupancy time for elongated TLOFs during takeoff and landing. For the purposes of this report, it was assumed that the capacity of an elongated TLOF, with a parallel taxiway and a suitable number of parking positions, would be approximately that of a runway used by aircraft of a weight comparable to the CTR-22C.

The capacity of a one-runway airport is 44 to 62 operations per hour. The capacity of a two-runway airport with a similar configuration to the Mansfield vertiport layout is 60 to 80 operations per hour.

CTR flights can be terminated or originated at the CTR parking positions, the cargo hangar, or the apron north of the storage hangars. A total of 25 to 30 aircraft parking positions would have to be provided to equal the capacity of the TLOFs.

There is sufficient area to park 14 CTRs at the vertiport as depicted, and the number of spaces available for CTR parking could be increased within the confines of the site. The vertiport capacity as depicted, with 14 parking spaces is approximately 36 operations per hour (14 x 2.6).

9.4.2 V/STOL Performance Characteristics

9.4.2.1 VFR/IFR Procedures

This site would allow precision instrument approaches. Precision instrument approaches are shown to TLOF 5 and TLOF 32, a nonprecision instrument approach to TLOF 23, and a visual approach to TLOF 14. The precision instrument approaches were selected to keep the approaches separated by at least 90-degrees to maximize wind coverage, to ensure that the part of the approach surface that is up to 35 feet above FATO elevation is within the vertiport boundary, and to position the TLOFs in the northeast quadrant of the parcel to maximize use of available land. In addition, the precision instrument approaches located in this way allow the placement of HALS within the same parcel.

Although the Mansfield site is in a suburban area, the area itself is sparsely populated. Either straight-in/straight-out or traffic pattern procedures are appropriate. Providing ground-based navaids for the final approach fix would be quite feasible. As discussed previously, a GPS waypoint, could serve as a final approach fix.

9.4.2.2 ATC Issues

ATC staff at Dallas-Fort Worth approach control would be expected to provide ATC (arrival/departure/local) services for the vertiport. At the beginning, the suburban location may result in a lower level of CTR activity than at an urban or downtown location, and most likely would not require an ATC tower. However, if helicopter plus CTR activity develops sufficiently, a control tower could be located at the vertiport.

9.4.2.3 Airside Security and Emergency Access

Security fencing is shown around the movement area to deny access to the movement area without first passing through a fence gate, hangar, or terminal building.

9.4.2.4 Aircraft Separation Standards

Wake turbulence may be a concern in planning the Mansfield vertiport if a high level of activity develops. If such activity occurs, a control tower might be needed. Controllers could then advise pilots of wake turbulence avoidance measures. The separation between the parallel taxiway and TLOF, and between the parallel taxiway and parking positions, allows use of each without affecting the other. The storage/maintenance hangars and cargo hangar are set back from the taxiway to allow a CTR to be parked in front of the hangars without affecting the taxiway. Although the orientation of the TLOFs; separation between

the TLOFs and parallel taxiway; separation between the parallel taxiway and terminal, parking positions, and hangars appears to be adequate, the effects of potential rotorwash are of concern. Due to the fact that the CTRs will be operated in the STOL mode, rotorwash effects are likely to be less than those experienced in VTOL mode.

9.4.3 Terminal Building Facilities

9.4.3.1 Aircraft Gates

There are six CTR parking positions or gates. Passengers will proceed between the gates and the terminal building via striped walkways.

9.4.3.2 Passenger Handling Facilities

The 8,000 square foot terminal is able to accommodate all passenger handling functions: lobby, concessions, baggage claim, ticket counter, security, rental car offices, and ATOs. Originating passengers enter the terminal from the auto parking lot, proceed with ticketing and baggage check-in, then proceed through security, to the hold room and on to the aircraft. Deplaning passengers exit the aircraft to the terminal building and proceed to the parking lot. The number of gates makes transfer passengers a possibility. Transfer passengers exit the aircraft and enter the terminal, and then exit the terminal to the aircraft when the aircraft is ready for boarding.

9.4.3.3 Airline Ticket Offices (ATO)

The terminal is large enough to accommodate all ATO functions.

9.4.3.4 Cargo/Baggage Handling

Cargo, particularly high value cargo, is very feasible for CTR flights in some settings. Due to its size and location, the Mansfield site is the only site with the capability to accommodate a cargo operation at the vertiport. A 180 foot by 80 foot (14,400 square feet) cargo hangar is located west of the CTR parking positions. The cargo apron accommodates two CTRs. The cargo apron and hangar are able to accommodate large cargo items, as well as small package express cargo carried on passenger flights. Deplaned cargo from the passenger aircraft can be transported to another passenger aircraft at the gate, or across the apron to the cargo apron/hangar to be included on a cargo flight. The area south of the cargo hangar is provided for truck access. Cargo to be enplaned on cargo flights can be transported by car or truck to the cargo terminal, processed, and transported to the CTR on the cargo apron.

9.4.3.5 Automobile Parking/Rental Car/Access Road

A 384,000-square feet parking area with a capacity of approximately 1,000 vehicles is depicted. Access to a suburban vertiport will be primarily by automobile. The loading area

for the cargo terminal is not included in the parking area. There is sufficient area near the terminal building for buses, taxis, short-term parking, and curb parking to drop off passengers.

Areas for rental car offices related to passenger services are available inside the terminal. Rental car ready lots and drop-off lots are provided in the parking area.

Access to the vertiport is via the proposed extension of Lone Star Road. If Lone Star Road is not extended, which is currently what the city of Mansfield planning department recommends, Lone Star Road would have to be extended from Johnson Street to the vertiport access road as part of vertiport development.

9.4.4 Aircraft Support Facilities

9.4.4.1 Maintenance Area

Three CTR hangars are located west of the cargo hangar. Each of these CTR hangars (130 feet by 110 feet) are sized to accommodate one CTR-22C. The hangar area can be developed to accommodate larger or additional hangars by extending the hangar area to the west.

As depicted, the hangars can be used for aircraft storage or maintenance. Since area is available, the vertiport could serve as a CTR maintenance base in support of both passenger and cargo operators. A benefit is realized if operators can fly to a maintenance base that is part of their route structure. There are a sufficient number of CTR parking positions, as well as area in front of the CTR hangars, to accommodate CTR maintenance without curtailing operation of the vertiport.

9.4.4.2 Fueling Facilities

There is sufficient area at the vertiport to develop a fuel farm with in-ground fueling to each of the six CTR parking positions. It is not recommended that hose reel fueling be used due to the number of CTR parking positions and the capability of the vertiport to accommodate a high number of operations. A recommended method, less expensive than in-ground hydrant fueling, is for a fuel truck, or a number of fuel trucks, to be loaded with fuel at the fuel farm and be parked where noted in figure 39. The fuel trucks can proceed to the CTR parking position, cargo apron, or hangar apron to fuel aircraft as necessary. An above-ground tank is recommended to minimize installation costs and to allow better monitoring of fuel tank operation. The fuel system should be installed according to NFPA and local guidelines.

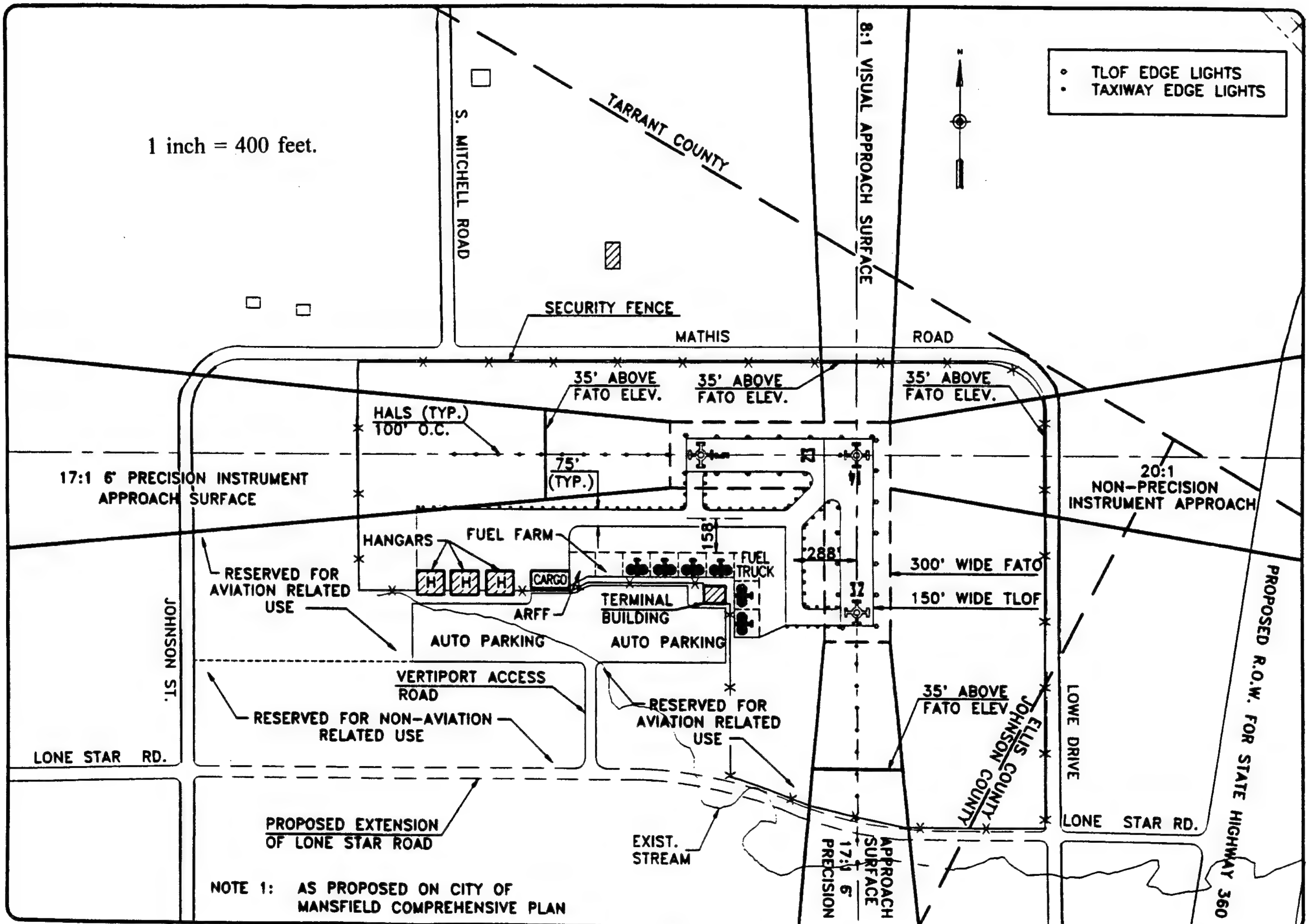


FIGURE 39 SITE PLAN - NEW VERTIPORT, MANSFIELD, TEXAS

9.4.4.3 Aircraft Rescue and Firefighting (ARFF)

There is sufficient area west of the fuel farm to provide full Index A ARFF capability. The area reserved for ARFF could accommodate a building to house the level of ARFF equipment, agents, and personnel described in section 7.3.

9.4.4.4 De-icing Equipment

Mechanical snow removal methods, as described in section 7.5.1, are sufficient due to the very low amounts of snow and ice that typically occur in the Mansfield area.

9.4.4.5 Automated Surface Observation System (ASOS)

An ASOS should be provided at the vertiport using the rationale described in section 7.5.2.

9.4.5 Intermodal Connections

The vertiport is located next to U.S. 287 and the proposed right-of-way for State Highway 360 (this highway proceeds to DFW International Airport). Bus service in Mansfield could be extended to the vertiport. Intermodal connections would primarily be limited to the number of CTR passengers using bus and taxi service at the vertiport.

9.4.6 Land Use

9.4.6.1 Noise Footprint

Another extremely critical issue is the need to provide enough land for noise mitigation, particularly in residential areas. Noise impact may be the most important determinant in public acceptance of CTR transportation. The present estimates of noise impact would require as much as 120 acres of noise compatible land around the facility to encompass the L_{dn} 65 dB noise contour. It is anticipated that future aircraft designs may reduce noise impact on communities. However, although the exact amount of land would vary from site to site, planners need to be aware of the potential real estate requirements.

9.4.6.2 Vertiport Land Area

The Mansfield site encompasses an area of 180 acres. This area includes all vertiport functions and facilities except for two HILS stations south of the extension to Lone Star Road. The area required for the HALS (approximately 3 acres) can be acquired in fee simple or controlled through easement.

9.4.6.3 Impact on Land Use

The areas around the vertiport are somewhat sparsely populated. The site is surrounded by agricultural uses. Residences are located along the northwest end of Mathis Road and south

of the intersection of Harmon Road and Davis Drive. Residences are located along Mathis Road. These residences may be subjected to CTR noise due to proximity to TLOF 5-23. This noise can be minimized by limiting TLOF 5 arrivals and TLOF 23 departures to only those times when wind conditions require use.

The Mansfield site is the only site with substantial expansion capabilities. The areas noted "Reserved For Aviation Related Use" could be developed for additional apron, hangar, cargo, or auto parking uses, or for manufacturing or commercial businesses requiring direct access to the vertiport movement area. The area noted "Reserved For Non-Aviation Related Use" could be developed for such uses as restaurants, rental car ready lots, manufacturing, or office uses. The revenue gained from development and leasing of these areas would serve to help offset capital and other costs for development and operation of the vertiport.

9.4.7 <u>Summary - New Vertiport, Mansfield, Texas</u>

The Mansfield site is the only site that can provide all of the services typically found at a commercial airport (terminal building, cargo, and maintenance). The two TLOFs provide a high degree of wind coverage, and the parallel taxiways provide a high degree of capacity and efficiency. Maintenance can be accomplished without affecting operation of the vertiport.

The Mansfield site is the only site discussed in this study for which potential is not constrained by the physical dimensions of the site and/or its surroundings. Suburban sites appear to be a paradox. Although there is sufficient area to develop a complete facility to the full extent of current and future requirements, passenger and other activity levels probably would not be as high as at a downtown location. However, suburban facilities such as Mansfield, can provide the services required to satisfy the needs of a complex urban system, such as fuel, maintenance, and hangars, in places where land is more available and less expensive. For example, Mansfield is ideally located to be the service center for both Dallas and Fort Worth, as well as other smaller vertiports that could be developed. If so, this would comprise a complete urban system.

The findings of the CTRDAC stress the importance of locating vertiports in close proximity to passenger demand centers. On this basis, it is questionable whether the Mansfield site would be acceptable.

9.5 ON-AIRPORT - JFK INTERNATIONAL AIRPORT, NEW YORK, NEW YORK

This vertiport site at the JFK International Airport was first discussed in the 1991 report, "Tilt Rotors and the Port Authority of New York and New Jersey Airport System." The site plan for the proposed vertiport is presented in figure 40. As discussed in section 3.0, an ongoing project at the airport as of this writing includes relocation of taxiways "I" and "O." If that expansion occurs, this site will no longer be available for vertiport development.

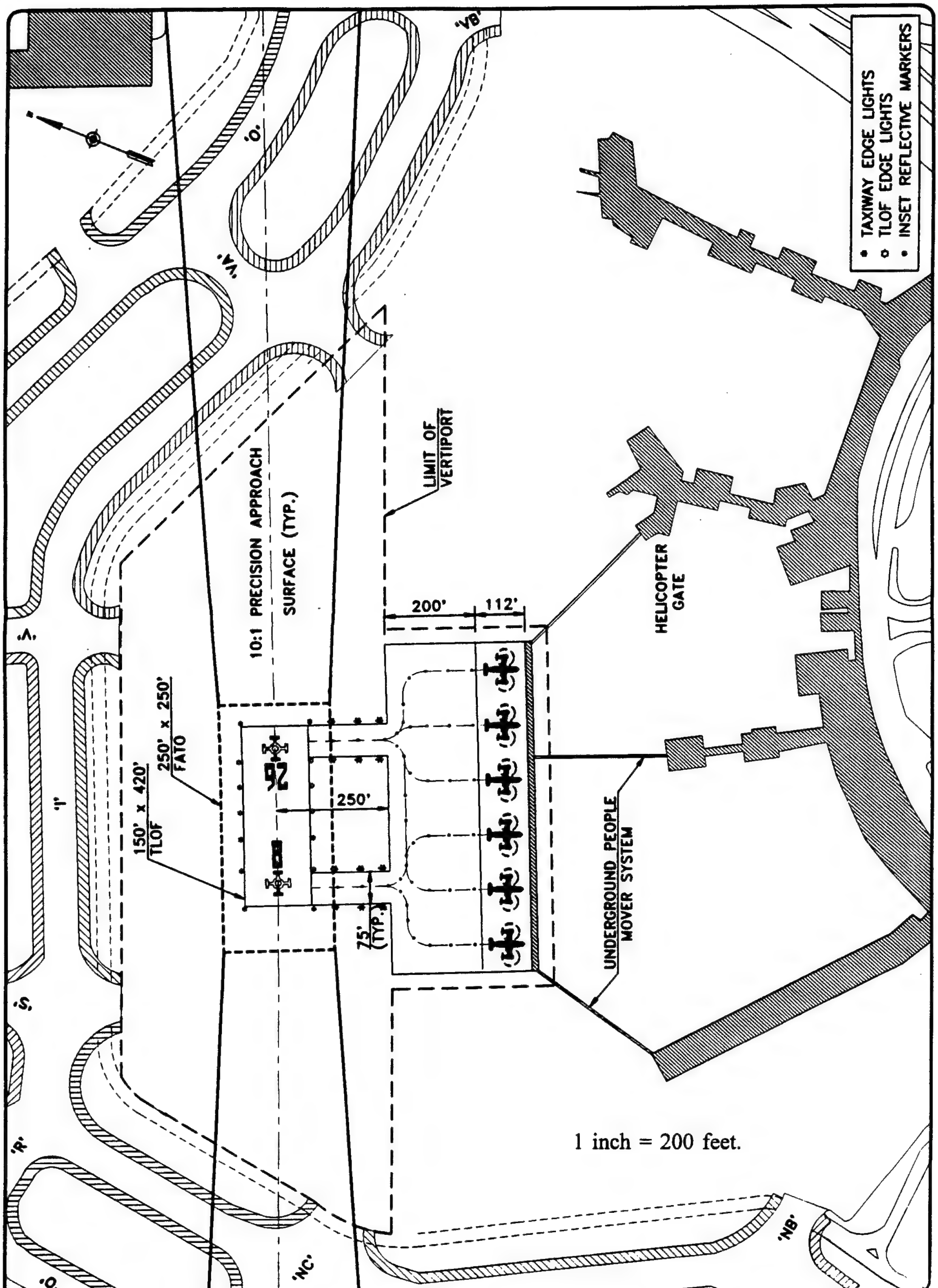


FIGURE 40 SITE PLAN - JFK INTERNATIONAL AIRPORT, NEW YORK

9.5.1 Airfield Facilities Provided/Operational Capacity

9.5.1.1 Takeoff and Landing Area Facilities

The TLOF/FATO is oriented parallel to the east-west section of relocated taxiways "I" and "O" to have the maximum area available. The TLOF/FATO as positioned allows a parallel taxiway and CTR parking positions without significantly affecting fixed-wing aircraft access to the existing finger terminals.

There is a large, clear, paved aircraft apron that provides a 650 foot long area from the center of TLOF 8, and 600 feet from the center of TLOF 26, to accommodate RTO and FAR Part 29 OEI requirements. The clear areas described are outside of the "object free area of taxiway" "I." This is based on FAA AC, "Airport Design," that shows the "taxiway object free area" for a taxiway used by a Boeing 747-400 to be 320 feet wide, 160 feet either side of taxiway centerline. The 400 foot rollway would allow CTRs to operate in a STOL mode rather than a VTOL mode.

9.5.1.2 Aircraft Parking Facilities

Six CTR gate positions are located near the terminal building in a configuration that avoids interference with fixed-wing aircraft access to the finger terminals. The CTR gate positions, as depicted, are sized 175-feet square to accommodate the CTR-22C. Additional gate positions can be provided and/or the size of the CTR gate positions can be increased by extending the parking area to the east and west, and towards the finger terminals. However, extension of the gate area could encroach upon the object-free areas associated with the fixed-wing taxiways leading to the finger terminals.

Space is available for six gate positions without adversely affecting fixed-wing traffic. The size of the TLOF and the dual taxiway arrangement minimizes the time that CTRs will require for takeoff and landing. In fact, operations should resemble fixed-wing operations from a conventional runway. Therefore, overall capacity of the facility will probably be dependent on gate availability. Vertiport design tradeoffs due to the effects of rotorwash need to be considered. These tradeoffs involve the consideration of safety, capacity, and land requirements (gate separations). (See section 4.3.3 for full discussion.)

9.5.1.3 Taxiways

The parallel taxiway and apron to the CTR parking positions allows ground taxiing rather than hover taxiing, so rotorwash and engine exhaust would be of minimal concern.

9.5.1.4 Pavement

The vertiport movement areas should be constructed of PCC to maintain pavement life, as are other runways and ramps at the airport.

9.5.1.5 Marking and Lighting

The precision instrument approaches to TLOF 8 and TLOF 26 require HILS and HALS. The taxiway is lighted with medium intensity centerline lights. PAPIs should be provided for visual and nonprecision instrument TLOF 8 and TLOF 26 approaches.

9.5.1.6 Peak Hour - Annual Capacity

Using FAA AC 150/5360-5, the annual service volume of a one-runway airport configured such as the vertiport at JFK would be 210,000 operations, but the capacity of a vertiport is constrained by the number of CTR parking positions. Applying the relationship of hourly capacity of 60 to 80 operations and annual service volume of 210,000 for airports to hourly vertiport capacity of 15.6 operations results in an annual service volume of approximately 57,000 annual operations (ACAP = HCAP x H x D x W, section 4.1.2)

However, an hourly capacity of 15.6 operations or an annual service volume of 57,000 is very dependent on the air traffic procedures that are used, or may be developed, at JFK International Airport.

It is assumed that each parking position or gate has a capacity of 2.6 operations per hour. Total gate capacity at the JFK vertiport would then be 15.6 operations per hour. It was previously stated that each CTR operation would occupy the TLOF for an average of 6 minutes (section 4.1.1). Assuming an adequate number of parking positions or gates and a parallel taxiway, each CTR operation would occupy the TLOF for less than 6 minutes per operation.

9.5.2 V/STOL Performance Characteristics

9.5.2.1 VFR/IFR Procedures

The actual flight tracks used for approaches/departures at the vertiport are dependent on approach/departure tracks used for the airport as a whole, as well as the tracks required by the air traffic controllers to sequence CTR activity with fixed-wing activity.

For the purposes of discussing this site, a Boeing 747-400 (tail height of 64 feet) could be taxiing on taxiway "I" and not obstruct imaginary surfaces of the vertiport. A precision instrument approach requires at least 640 feet (9-degree approach, 10:1 approach surface) or 1,088 feet (6-degree approach, 17:1 approach surface) between the center of the taxiway and the nearest edge of the FATO.

It is assumed that, per the AC, at least 75 feet is required between the edge of the FATO and the edge of the TLOF. A 6-degree approach is not feasible, as the resultant TLOF with a visual approach on the opposite end would be only 185 feet long. A 400 foot long TLOF may be possible with a 9-degree approach to both ends of the TLOF.

A 528 foot long TLOF may be possible with a 9-degree approach to one end of the TLOF and a visual approach to the other end of the TLOF. For discussion of this site, it is assumed that there is a 9-degree precision instrument approach to both ends of the TLOF. The TLOF/FATO in this position allows the CTR to taxi from the TLOF via taxiway "S," taxiway "V," taxiway "NC," or taxiway "VA" to other areas of the airport.

Sufficient navaids exist in the JFK airport environment to provide nonprecision instrument approach procedures to the vertiport. Precision instrument approaches would be provided by dGPS. The type of navaids used to support a final approach fix such as VOR radials, NDB, or dGPS, when developed, could be used for the TLOF 8 and TLOF 26 approaches.

9.5.2.2 ATC Issues

JFK tower air traffic controllers would provide control services at the vertiport and the New York TRACON (terminal radar approach control) would provide approach control functions. The volume of CTR operations may require the designation of a dedicated controller in the tower to handle aircraft movements. Even though imaginary surfaces for the TLOF 8 and TLOF 26 approaches would clear taxiway "I," it is expected that taxiing on taxiways "I" and "O" at the airport would be sequenced with arrivals and departures to the vertiport.

9.5.2.3 Airside Security and Emergency Access

Passengers can use existing terminals with existing security check facilities, so they can pass through security prior to leaving the terminal and entering the ramp and vertiport area. Additional security measures beyond those already existing at the airport are not required for the vertiport.

Existing airport emergency response personnel can serve the vertiport using the same procedures contained in the Airport Certification Manual (ACM) for responses to the ramp at the finger terminals.

9.5.2.4 Aircraft Separation Standards

Wake turbulence issues would be handled operationally by the sequencing instructions controllers give to pilots. Jet blast by "heavy" aircraft taxiing near the vertiport should not be an issue, as the jet blast would not be directed toward the vertiport. The CTR parking positions, parallel taxiway and TLOF/FATO, as depicted, are in compliance with design criteria in the FAA AC, "Vertiport Design."

9.5.3 Terminal Building Facilities

9.5.3.1 Aircraft Gates

There are six CTR parking positions or gates. Passengers can use the existing finger terminals for all terminal functions. Passengers can walk between the CTR parking positions and the finger terminals via striped walkways.

All passenger functions are assumed to be provided in the terminals. Passengers are required to walk at least 300 feet between the CTR parking positions and the terminals. A bus/van passenger transfer system is used presently at JFK as well as Dulles International Airport. Although not as efficient as a gate at the terminal, a bus transfer system is recommended to move passengers between aircraft and the terminal building to avoid pedestrians walking on the apron, which has a very high volume of both vehicular as well as aircraft traffic.

Another option similar to the new United terminals at Chicago-O'Hare and the new central terminal at Greater Pittsburgh International is an underground passageway between the terminal and vertiport. Such an underground tunnel would not interfere with apron activity and provide a safe means of access to the vertiport. That option, however, is very expensive, and may not be justified based on the level of activity at the vertiport.

9.5.3.2 Passenger Handling Facilities

All terminal functions for CTR passengers (i.e., security, hold room, baggage claim, ticketing, etc.) is provided by the existing finger terminals. Enplaning passengers pass through security check, collect in the departure lounges in the finger terminals, and proceed to the CTR parking positions when the CTR is ready for boarding. As a result, all enplaning passengers pass through security before exiting the finger terminal.

9.5.3.3 Airline Ticket Offices (ATO)

ATOs would be located in the existing finger terminals. All other typical terminal functions are provided at the airport and are available for use by the operator.

9.5.3.4 Cargo/Baggage Handling

Cargo terminals exist north of taxiway "O." Cargo and baggage handling is accomplished with facilities now at the airport. Existing airport security facilities can be used to check baggage and cargo as required.

9.5.3.5 Automobile Parking/Rental Car/Access Road

No additional automobile parking facilities, rental car facilities, or access roads have to be constructed for the vertiport, as they already exist at the airport.

9.5.4 Aircraft Support Facilities

9.5.4.1 Maintenance Facilities

There is not sufficient area for maintenance aprons or hangars at the vertiport site. CTR maintenance facilities could be developed in other areas of the airport or be co-located with existing fixed-wing maintenance facilities.

9.5.4.2 Fueling Facilities

Fuel trucks that are used at the airport would be used to fuel CTRs at the vertiport.

9.5.4.3 Aircraft Rescue and Firefighting (ARFF)

The ARFF capability at the airport far exceeds the requirements for the vertiport and would respond to vertiport emergencies.

9.5.4.4 De-icing Equipment

The same de-icing systems used to clear the ramp for the finger terminals can be used for the vertiport.

9.5.4.5 Automated Surface Observation System (ASOS)

All air traffic reporting and weather observation and reporting systems required for a vertiport presently exist at the airport.

9.5.5 Intermodal Connections

As vertiport passengers would be using an existing airport terminal, all transportation services available at the airport could be used (e.g., buses, limousines, taxis, as well as connection with scheduled air carriers).

9.5.6 Land Use

9.5.6.1 Noise Footprint

Noise impact is not anticipated to be an issue at this site since it is located on the airport.

9.5.6.2 Vertiport Land Area

As noted on figure 40, the vertiport encompasses an area of 29.6 acres. Since the vertiport would be located in the interior of the airport, typical land use concerns (traffic and noise) do not apply. The land use concerns that do apply are in relation to operation of the airport.

9.5.6.3 <u>Impact on Land Use</u>

The area where the vertiport is depicted is presently being planned and developed for extension of the finger terminals. If taxiways "I" and "O" are relocated and the terminals are not extended, areas would be available for the vertiport. If plans proceed with extension of the finger terminals, the vertiport as depicted could not be developed.

9.5.7 <u>Summary - JFK International Airport, New York, New York</u>

If the described area is actually available for the vertiport, the vertiport could be constructed easily within the existing airport infrastructure. Except for NAVAIDS and lights, no other facilities would have to be installed or constructed. The JFK site represents the least amount of required construction of all the vertiport sites in the analysis. The larger issue concerning the JFK site is whether or not the site is actually available, and if suitable air traffic procedures can be developed to efficiently integrate operation of the vertiport with operation of the airport.

10.0 ESTIMATES OF COSTS

Estimates of the cost to design and construct the vertiport facilities depicted in figures 32 to 39 were prepared to provide an understanding of the individual costs associated with each type of site. The costs are not meant to be comparative. The particulars of each site are so dissimilar as to preclude such a comparison.

Because of the unknowns about each site, the costs were prepared assuming a prepared site or, in the case of elevated facilities, an existing support structure of adequate strength. The costs account for such items as pavement, drainage, lighting, navaids, fuel facilities, and any buildings (cargo, hangar, terminal, etc.). Not all sites can, or need to, have the same facilities. Some do not have adequate space and others have existing facilities nearby that can be shared. For example, existing terminal facilities such as the Amtrak Station in Washington, D.C. or the JFK airport terminal in New York could provide space for terminal services. These differences result in significantly different costs.

The costs do not reflect the potential level of activity of a site. The site at Mansfield, for example, reflects the layout possible at a site with a significant amount of area. As a suburban site, however, it would be expected to generate less traffic than one of the urban sites or the JFK International Airport site. The facilities for each were laid out to the extent allowed by the constraints of the location. Where there was room for more facilities, it is reflected in the higher cost of the vertiport (e.g., Mansfield). Where existing facilities reduced the vertiport construction needs, the vertiport cost is lower (e.g., JFK International Airport).

Each site cost estimate is comprised of an "engineer's estimate of cost" work sheet that summarizes the quantities and unit costs that make up the estimate and accompanying notes describing the assumptions made. The cost estimates are adjusted regionally based on data contained in the publication "Means Heavy Construction Cost Data, 1994," published by R.S. Means Company, Inc. Means provides national cost estimates for large construction projects, unit prices for materials, and adjustment factors for each part of the country.

10.1 UNION TERMINAL, CINCINNATI, OHIO

ENGINEERS ESTIMATE OF COST

PROJECT	Union Terminal	SHEET NO.	1 of 1
SUBJECT	Cincinnati, Ohio	JOB NO.	
		BY/DATE	DMC
		CHKD. BY/DATE	
Means Div. 2 Local Cost Index = 96.3			

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	8' Security Fence	LF	2,700	15.00	40,500.00
	24' Drive Gate	EA	3	2,000.00	6,000.00
	New Fuel Farm & Refueling Equipment	LS	1	250,000.00	250,000.00
	Semiflush Omni-directional Edge Lights	EA	53	1,400.00	74,200.00
	1/C #8 5KV, L-824 Cable	LF	2,300	1.10	2,530.00
	#8 Bare Copper Counterpoise	LF	2,100	1.10	2,310.00
	Vertiport Beacon	EA	1	11,000.00	11,000.00
	Lighted Wind Cone	EA	1	6,000.00	6,000.00
	Remote Controls	EA	1	12,000.00	12,000.00
	Parking Edge Lights	EA	16	1,300.00	20,800.00
	2" 1 Way Duct Concrete Encased	LF	2,000	6.00	12,000.00
	New Regulator & Asso. Elec. Equipment	LS	1	25,000.00	25,000.00
	Pavement Marking	SF	2,000	1.00	2,000.00
	Bit. Pavement Removal	SY	15,590	1.50	23,385.00
	Airport Bituminous Pavement	TON	3,165	35.00	110,775.00
	Bituminous Prime Coat	GAL	2,800	1.50	4,200.00
	Bituminous Tack Coat	GAL	1,850	1.50	2,775.00
	Small Electrical Vault	LS	1	25,000.00	25,000.00
	P-209 Crushed Agg. Base Course	CY	2,600	20.00	52,000.00
	Common Excavation	CY	5,200	4.00	20,800.00
	6" Light Duty PCC TLOF (concrete)	CY	6,335	35.00	221,725.00
	Aircraft Rescue & Firefighting Equip	LS	1	50.000.00	50,000.00
	Mechanical De-icing Equipment	LS	1	50,000.00	50,000.00
	Automated Surface Observation System	LS	1	95,000.00	95,000.00
	Precision Approach Path Indicator	EA	2	21,500.00	43,000.00
	Total to Construct				1,163,000.00
	Engineering & Contingency (25%)				290,750.00
	TOTAL				1,453,750.00

CINCINNATI, OHIO - ESTIMATE ASSUMPTIONS

BITUMINOUS PAVEMENT REMOVAL - This estimate will assume that all areas of new bituminous pavement will have pavement removed.

570 * 180 = 103,600 SF
75 * 210 = 15,750 SF
110 * 120 = 13,200 SF
131,550 SF/9 = 14,616 SY +5% **Say** 15,350

AIRPORT BITUMINOUS PAVEMENT P-401 - Use 15,350 SY for estimate (see above).

(15,350)(0.057)(6) = 5,250 **Say** 5,300 TON

P-209 CRUSHED AGG. BASE COURSE - (9)(15,350 SY)(6/12)(1/27) = 2,558 CY
Say 2,600CY

COMMON EXCAVATION - (15,350)(9)(1)(1/27) = 5,116 CY
Say 5,200 CY

SECURITY FENCE - 1,100' + 1,000 + 130 + 160 + 220 = 2,610 **Say** 2,700

FUEL FARM - Lump Sum **Say** $40,000.00

SEMIFLUSH - All lights on perimeter of TLOF and ℄ lights to parking area are semiflush.
Say 53

1/C #8, L-824 CABLE - 1,000' + 280' + 520 + 300 = 2,100 LF +5% **Say** 2,300 LF

#8 BARE COPPER COUNTERPOISE - 1,000 + 280 + 520 + 150 + 5% **Say** 2,100 LF

Vertiport Beacon - 1
Lighted Wind Cone - 1
Remote Controls - 1
Parking Area Edge Lights - (elevated) **Say** 16
2" 1-Way Duct Concrete Encased 200 + 1,000 + 280 + 520 = 2,000 +5%**Say** 2,100

#8 FUELING SYSTEM - 10,000 GAL above ground tank, self contained with hose reel and cabinet.

10.2 GREYHOUND BUILDING, PHOENIX, ARIZONA

ENGINEERS ESTIMATE OF COST

PROJECT	Greyhound Building Vertiport	SHEET NO.	1 of 1
SUBJECT	Phoenix, Arizona	JOB NO.	
		BY/DATE	DMC/12-9-93
		CHKD. BY/DATE	
Means Div. 2 Local Cost Adjustment = 91.8			

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	Terminal Building w/Elevator	LS	1	500,000.00	500,000.00
	6" Light Duty PCC TLOF (concrete)	LS	1	150,000.00	150,000.00
	Fuel Storage and Refueling Equipment	LS	1	250,000.00	250,000.00
	8' Security Fence	LF	300	15.00	4,500.00
	24' Drive Gate	EA	1	1,000.00	1,000.00
	1/C #8 5KV, L-824 Cable	LF	900	1.00	900.00
	Semiflush Omni-directional Edge Lights	EA	16	1,200.00	19,200.00
	#8 Bare Copper Counterpoise	LF	700	1.00	700.00
	2" PVC Conduit in Slab	LF	700	4.00	2,800.00
	Vertiport Beacon	EA	1	10,000.00	10,000.00
	Lighted Wind Cone	EA	1	6,000.00	6,000.00
	Radio Controls	EA	1	12,000.00	12,000.00
	Pavement Marking	SF	2,000	1.00	2,000.00
	New Lighting Regulator	EA	1	10,000.00	10,000.00
	Precision Approach Path Indicator	EA	2	20,000.00	40,000.00
	Aircraft Rescue and Fire Fighting Equip	LS	1	65,000.00	65,000.00
	Automated Surface Observation System	LS	1	95,000.00	95,000.00
	Total to Construct				1,169,100.00
	Engineering & Contingency (25%)		(25%)		292,275.00
	TOTAL				1,461,375.00

PHOENIX, ARIZONA - ESTIMATE ASSUMPTIONS

NEW ROOFTOP TLOF - The estimated cost for the new rooftop TLOF will include a 270' x 325' structural concrete TLOF with all associated framework. Estimated @ $15/SF.

100' x 100' * 15 = $150,000

Cost of TLOF is to include vehicle ramp access, parking area and associated security measure.

FUEL AREA - Assume tank at ground level fueling hose reel and cabinet filter etc. on roof. Assume above ground self contained tank of approximately 10,000 gal. **Say** $250,000

8' SECURITY FENCE - Fencing only used on east side from terminal building to fuel storage area.

40' + 210' + 20' + 20' = 290' **Say** 300 FT

1/C #8, 5 KV, L-824 TYPE C CABLE

130' + 130' + 130' + 130' + 150*2

Total = 820 + 5% **Say** 900 LF

#8 BARE COPPER COUNTERPOISE & 2" PVC CONDUIT IN SLAB

130' + 130' + 130' + 130' + 150'

Total 670 LF + 5% **Say** 700 LF

VERTIPORT BEACON - 1 EA - Estimate to include cost of wire and conduit. **Say** 1

LIGHTED WIND CONE - 1 wind cone will be visible from all sides. **Say** 1

RADIO CONTROL - **Say** 1

TERMINAL BUILDING - : This will be a basic building without significant options. Estimated at $85/SF 40' x 100'= $340,000, + Elevator @ $100,000, + lighting vault @ $60,000.

Say $500,000

Will include utilities if it is assumed that they are available on roof or not more than 1 floor below roof.

10.3 UNION STATION, WASHINGTON, D.C.

ENGINEERS ESTIMATE OF COST

PROJECT	Washington, D.C.	SHEET NO.	1 of 1
SUBJECT	Union Station	JOB NO.	
		BY/DATE	DMC/12-29-93
		CHKD. BY/DATE	
Means Div. 2 Local Cost Index = 91.1			

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	New Overhead TLOF	LS	1	1,386,000.00	1,386,000.00
	New Electrical Vault	LS	1	16,000.00	16,000.00
	Semiflush Omni-directional Edge Lights	EA	16	1,200.00	19,200.00
	1/C #8, 5KV L-824 Cable	LF	2,000	1.00	2,000.00
	#8 Bare Copper Counterpoise	LF	1,000	1.00	1,000.00
	2" PVC Conduit in Slab	LF	1,000	4.00	4,000.00
	New Regulator & Asso. Equipment	LS	1	25,000.00	25,000.00
	Parking Flood Lights	EA	2	1,800.00	3,600.00
	Pavement Marking	SF	1,000	1.00	1,000.00
	Vertiport Beacon	EA	1	10,000.00	10,000.00
	Lighted Wind Cone	EA	1	6,000.00	6,000.00
	Remote Controls	EA	1	12,000.00	12,000.00
	Hazard Beacons	EA	10	1,800.00	18,000.00
	Safety Net	SF	10,500	2.55	26,775.00
	Elevator	LS	1	100,000.00	100,000.00
	Fueling System	LS	1	250,000.00	250,000.00
	Extend Utilities - Water, Drainage, Elect.	LS	1	100,000.00	100,000.00
	Precision Approach Path Indicator	EA	2	20,000.00	40,000.00
	Pavement Heating system	SF	67,900	7.50	509,250.00
	Automated Surface Observation System	LS	1	95,000.00	95,000.00
	Aircraft Rescue and Fire Fighting Equip	LS	1	60,000.00	60,000.00
	Total to Construct				2,684,825.00
	Engineering & Contingency (25%)				671,206.25
	TOTAL				3,356,031.25

WASHINGTON, D.C. - ESTIMATE ASSUMPTIONS

NEW OVERHEAD TLOF - This estimate will assume that the existing structure is structurally strong enough to hold another floor on top of the existing top floor.

TLOF Size = 220 x 420 = 92,400 SF
Cost Estimates @ $15.00/SF = $1,386,000

NEW ELECTRICAL VAULT - All electrical equipment shall be stored in a small vault that can be built on the existing roof.

Vault size is 20' x 20'= 400 SF, Approximately $40/SF = $16,000

ELECTRICAL VAULT EQUIPMENT

Semiflush Edge Lights	- 16 EA	
1/C #8, 5 KV, L-824 Cable	- 2000 LF	
#8 Bare Copper Counterpoise	- 1000 LF	
2" PVC Conduit in Slab	- 1000 LF	
New Regulator & Associated Vault Equipment		-LS
Vertiport Beacon	- 1 EA	
Lighted Wind Cone	- 1	

SAFETY NET - Cost taken from "Means Building Construction Cost Data," 1993.

13,000 SF * $2.55/SF = $26,775.00

ELEVATOR - Install New Elevator to travel two Floors @ $100,000

FUELING SYSTEM - One 10,000 gal above ground tank at ground level, self contained. Pump to roof @ $250,000.

EXTEND EXISTING UTILITIES TO NEW LEVEL - Water, drainage, electrical = approximately $100,000

PAVEMENT HEATING SYSTEM - Cost taken from "Means Building Construction Cost Data," 1993.

Electric heating snow melting for paved surface embedded mat heaters and controls.
$8.15/SF * (91.5÷100) = $7.46 SF **Say** $7.50/SF

Areas to be heated:
TLOF = 22,500 SF, TAXIWAY = 23,400 SF, PARKING = 22,000 SF Total 67,900 SF; for $509,250.

WASHINGTON, D.C. - ESTIMATE ASSUMPTIONS (continued)

FIRE PROTECTION - Cost taken from "Means Building Construction Cost Data," 1993.

Diesel fire pumps - 500 GPM,50 PSI, 25 HP, 4" pump @ $45,800
Tank - 5,000 @ $2,325
Fire hose and misc. equipment @ $10,000
Total $58,125 **Say** $60,000

10.4 NEW VERTIPORT, MANSFIELD, TEXAS

ENGINEERS ESTIMATE OF COST

PROJECT	Mansfield, Texas Vertiport	SHEET NO.	1 of 2
SUBJECT		JOB NO.	
		BY/DATE	DMC/12-29-93
		CHKD. BY/DATE	
Means Div. 2 Local Cost Index = 102± (Based on Dallas Index)			

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	8' Security Fence	LF	10,100	15.00	151,500.00
	24' Drive Gate	EA	2	2,000.00	4,000.00
	Airport Bit. Conc. Pavement	TON	24,000	35.00	840,000.00
	P-209 Airport Subbase	CY	27,000	23.00	621,000.00
	6" Light Duty PCC TLOF (concrete)	SY	43,200	40.00	1,728,000.00
	Bituminous Tack Coat	GAL	10,400	2.00	20,800.00
	Bituminous Prime Coat	GAL	30,000	2.00	60,000.00
	6" Underdrain	LF	3,500	15.00	52,500.00
	6" Underdrain Cleanout	EA	15	300.00	4,500.00
	Catch Basin/Manhole 4' Dia.	VF	150	230.00	34,500.00
	15" Storm Drain Pipe	LF	1,500	25.00	37,500.00
	Well	LS	1	150,000	150,000.00
	Septic System	LS	1	150,000	150,000.00
	Stream Relocation	LF	2,600	150.00	390,000.00
	Unclassified Excavation	CY	25,000	4.00	100,000.00
	Erosion Control	LS	1	25,000.00	25,000.00
	Loam & Seed	SY	25,000	1.25	31,250.00
	Install A/P Reg. & Asso. Equipment	LS	1	40,000.00	40,000.00
	1/C #8, 5KV, L824 Type C Cable	LF	15,000	1.00	15,000.00
	#8 Bare Copper Counterpoise	LF	10,000	1.00	10,000.00
	Vertiport Beacon	EA	1	11,000.00	11,000.00
	Lighted Wind Cone	EA	2	6,000.00	12,000.00
	Semiflush Omni-directional Edge Light	EA	60	1,600.00	96,000.00
	Elevated Edge Light	EA	150	1,100.00	165,000.00
	Taxiway Edge Light	EA	50	800.00	40,000.00
	Elevated Threshold Light	EA	50	1,100.00	55,000.00
	Elevated HALS	EA	60	1,600.00	96,000.00
	4" 4-Way Concrete Encased Duct	LF	800	25.00	20,000.00
	Parking Position Flood Lights	EA	10	2,000.00	20,000.00

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	EMH	EA	10	3,200.00	32,000.00
	2" 1-Way Concrete Encased Duct	LF	700	6.00	4,200.00
	PAPI	EA	1	23,000.00	23,000.00
	VGSI	EA	3	23,000.00	69,000.00
	Radio Controls	EA	2	13,500.00	27,000.00
	Guidance Signs	EA	8	2,300.00	18,400.00
	Terminal Building	LS	1	750,000.00	750,000.00
	Fuel Farm & Fuel Hydrant System	LS	1	300,000.00	300,000.00
	Pavement Marking	SF	12,000	1.25	15,000.00
	Landscape Allowance	ALL	1	10,000.00	10,000.00
	Cargo Building	LS	1	1,040,000	1,040,000.00
	Hangars	LS	3	812,500.00	2,437,500.00
	Automated Surface Observation system	LS	1	108,100.00	108,100.00
	Index A ARFF	LS	1	412,000.00	412,000.00
	De-Icing Equipment	LS	1	50,000.00	50,000.00
	Total Construction Costs				10,276,750.00
	Engineering & Contingency (25%)				2,569,188.00
	TOTAL				12,845,938.00

MANSFIELD, TEXAS - ESTIMATE ASSUMPTIONS

FENCE - The entire vertiport is enclosed with 8' security fence. Quantity scaled of site plan -

2900 LF	800 LF		
1000 LF	1,500 LF		
1650 LF	2,200 LF	Total = 10,050	**Say** 10,100 LF

PAVEMENT -

Auto Parking - Assume 3" Bituminous Conc. Pavement

50' * 500'	=	25,000 SF
250' * 1,450'	=	362,500 SF
700' * 100'	=	70,000 SF
Total	=	50,834 SY

50,834 * .057 * 3' = 8,693 tons

Area near hangars - 700' * 300' * 1/9 * .057 * 4" = 5,320 ton = 5,320 tons
Area in front of apron - 1,100' * 200' * 4" * .057 * 1/9 = 5,574 = 5,574 tons
350 * 200' * 4" * .057 * 1/9 = 1,774 = 1,774 tons

Taxiway to TLOF 5 - 80 * 180 * 4" * .057 * ¼ = 365 ton = 365 tons
Taxiway to TLOF 32 - 80 * 180 * 4" * .057 * ¼ = 365 = 365 tons
Taxiway to TLOF 14 - 300 * 150' 4' * 0.057 1SY/9SF = 760 = 760 tons

Total 22,851
+ 5%
23,994 **Say** 24,000 tons

TLOF 5-23 AND 14-32

850 * 150 * 4 * 0.057 * 1/9	= 3,230	=3,230 tons
700 * 150 * 4 * 0.057 * 1/9	= 2,660	=2,660 tons
300 * 150 * 4 * 0.057 * 1/9	= 1,140	=1,140 tons

Total = 20,121 +5% = 30,577 tons **Say** 30,200 tons

P-209 AIRPORT SUBBASE Assume 6"

Parking Lot Subbase 50 * 500 * 6/12 * 1/27 = 463 CY
250 * 1,450 * 6/12 * 1/27 = 6,713 CY
700 * 100 * 6/12 * 1/27 = 1,297 CY

Airside Subbase 700 * 300 * 6/12 * 1/27 = 3,889 CY (continued on next page)

Airside Subbase (continued)

	1,100 * 200 * 6/12 * 1/27 = 4,074 CY
	350 * 200 * 6/12 * 1/27 = 1,297 CY
	2 * 80 * 180 * 6/12 * 1/27 = 533 CY
	850 * 150 * 6/12 * 1/27 = 2,361 CY
	700 * 150 * 6/12 * 1/27 = 1,944 CY
	300 * 100 * 6/12 * 1/27 = 556 CY
Subbase Below PCC	125 * 900 * 6/12 * 1/27 = 2,083CY
	100 * 250 * 6/12 * 1/27 = 463CY
	25,673
	+5%
	26,956 — **Say** 27,000

6" LIGHT DUTY PCC PAVEMENT - Unit price includes sawcut control joints, steel dowels, wire mesh & crack seal.

125 * 900 * 1/9 =		12,500 SY
100 * 250 * 1/9 =		2,778 SY
	15,278 SY	

TLOF 5-23 & 14-32

850'*150'* 1SY/9SF=		14,167SY	
700'*150'* 1/9 =		11,667SY	
	25,834SY		
	41,112SY		
	+5%		
Total		43,168SY	**Say** 43,200SY

Prime Coat 30,000 GAL
Tack Coat 10,400 GAL

3 HANGARS NEAR CARGO AREA - Each floor approx. 125' x 100' @ $65.00/sf. Price to include sewer, water, offices, lounge & waiting area. Hangars will be for an FBO. - 3 EA

TERMINAL BUILDING - Estimate for 75' x 100' terminal building prepared @ $100/sf.

ONE FUEL FARM ESTIMATE - Assume 2, 10,000 gal above ground tanks, self contained, set up for truck filing.

CARGO BLDG - 80' X 200' @ $65.00/sf

LOAM & SEED - Estimate assumes that entire site already has topsoil on it and none will need to be brought in. Measured off of plans - **Say** 25,000 SY.

PRECISION APPROACH INSTRUMENTS - This estimate assumes a GPS will be in effect by then.

WELL AND SEPTIC SYSTEM - Assume that one well and one septic system will be developed on the site and that all building on the site will utilize them.

STREAM RELOCATION - 2,600 lf.

AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)

ls $108,100.00

AIRCRAFT RESCUE AND FIREFIGHTING EQUIPMENT

Full Index A ARFF Capability

• Primary Index A Response Truck		$190,000.00
• Equipment to be carried on truck and other equipment associated with the primary response	30,000.00	
• General purpose pick-up truck		17,000.00
• Fire Station	125,000.00	
• Equipment for Fire Station	50.000.00	

$412,000.00

DEICING EQUIPMENT

Only a small truck is needed due to small amounts of snow.

Say $50,000.00

10.5 JFK INTERNATIONAL AIRPORT, NEW YORK, NEW YORK

ENGINEERS ESTIMATE OF COST

PROJECT	JFK Airport	SHEET NO.	1 of 1
SUBJECT	Vertiport Estimate	JOB NO.	
		BY/DATE	DMC/12-7-93
		CHKD. BY/DATE	JBD/1-7-94
Means Div. 2 Local Cost Index = 123			

ITEM NO.	DESIGNATION	QUANTITY		COST	
		UNIT	AMOUNT	UNIT	TOTAL
	Pavement Marking	SF	8000	1.30	10,400.00
	1/C #8, 5 KV, L-824 Cable	LF	15,000	1.00	15,000.00
	#8 Bare Copper Counterpoise	LF	10,000	1.30	13,000.00
	Flush Mounted Omni-directional Edge Light	EA	42	1,500.00	63,000.00
	Semi-Flush, Unidirectional HALS	EA	60	1,700.00	102,000.00
	Semi-Flush, HILS	EA	24	1,700.00	40,800.00
	Lighted L-806 Wind Cone	EA	1	15,000.00	15,000.00
	Omni-directional T/W Edge Light	EA	25	1,500.00	37,500.00
	CTR Parking Flood Lights	EA	6	2,000.00	12,000.00
	New Regulator w/Associated Equipment	LS	1	35,000.00	35,000.00
	Taxiway Centerline Reflective markers	EA	50	55.00	2,750.00
	2" - 1 Way Concrete Encased Duct	LF	6,000	6.80	40,800.00
	Precision Approach Path Indicator (PAPI)	EA	2	20,000.00	40,000.00
	Total Construction Cost				427,250.00
	Engineering & Contingency (25%)				106,810.00
	TOTAL				534,060.00

JFK AIRPORT - ESTIMATE ASSUMPTIONS

PAPI - Existing equipment for instrument approach procedures will be used for both approaches. New PAPIs will be included for this estimate.

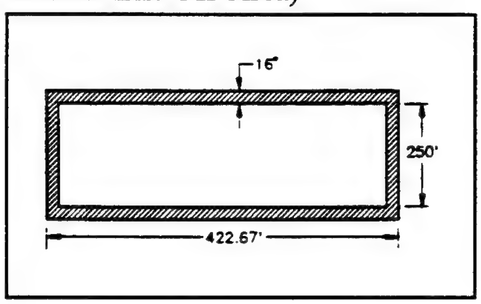
VERTIPORT BEACON - Wind indicator must be visible to pilots of approaching aircraft, and also must be lighted for night operations.

CTR PARKING FLOOD LIGHTS - Shielded parking flood light will be required for passenger safety en route to terminal.

Omni-directional T/W EDGE LIGHT - Taxiway edge light provided for ease of night navigation.

ELEC. VAULT UPGRADE - Separate circuit for vertiport will require a new regulator with associated equipment. NOTE: All areas are already paved

MARKING - • TLOF (Touchdown Lift Off Area)



2(422.67)(1.33) + 2(250)(1.33) = 1789.30 SF **Say 1,800 SF**

- NUMBERS

  8-26 Assume 300 SF/Letter 900 SF

- T/W Edge Stripes

160'	210'	180'	750
170'	170'	312'	750
170'	170'	312'	

3350 + 0.5 = 1,675 **Say 1,700 SF**

- ℄ LEAD-IN STRIPES

6 * 200	5 * 100
550	2 * 150
6 * 80	

Total Length = 3,030 **Say 1,550 SF**

3,030 * .5 = 1,515

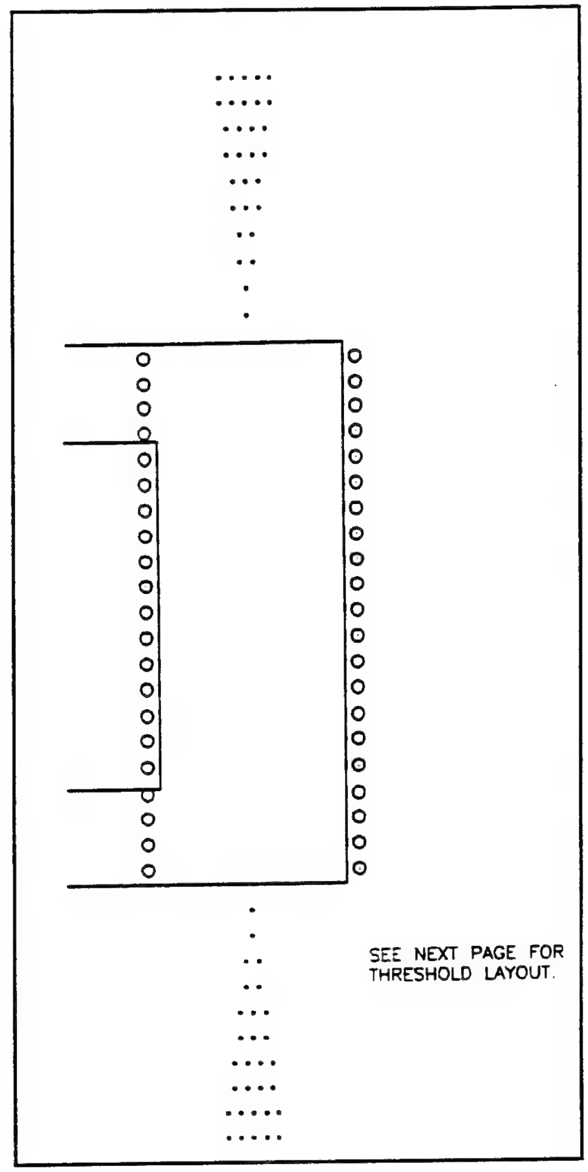
JFK AIRPORT - ESTIMATE ASSUMPTIONS (continued)

- WALKWAY EDGE STRIPES

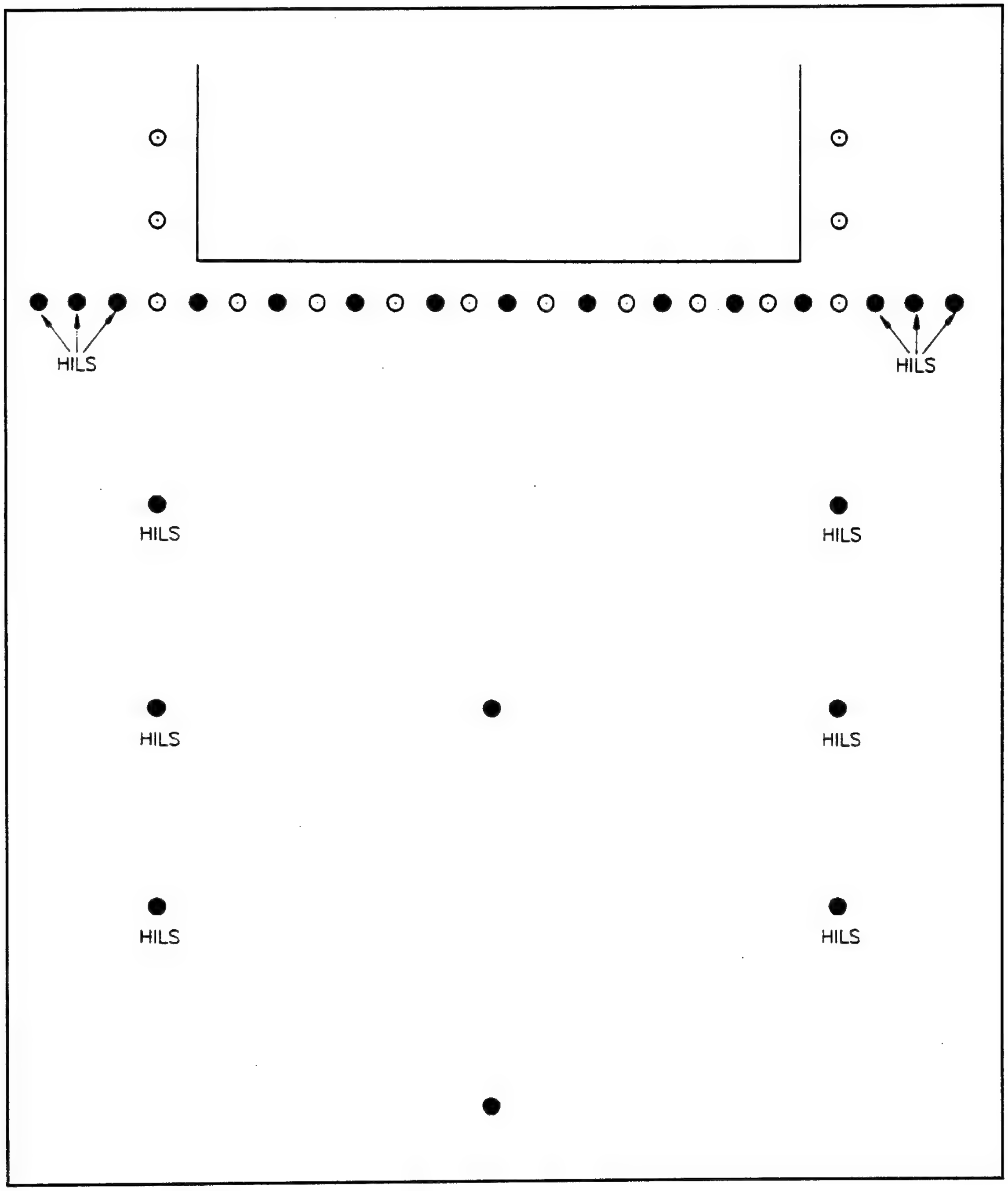
(0.5)(2)(980)	=	980 SF	**Say** 1,000 SF
Total Area	=	6,950 SF	**Say** 8,000 SF

LIGHTING ESTIMATE

42 - Omni-directional Flush Mounted
60 - Bi-directional Semiflush HALS System
24 - HILS (Semiflush)
15,000 LF 5 KV Cable
10,000 LF Counterpoise



LIGHTING ESTIMATE (continued) - Threshold Lights



NOTE: This configuration of lights is required for all precision approach vertiports. Therefore, this will be needed for both ends of the TLOF.

Table 9 presents a summary of vertiport development costs of the five sites selected.

TABLE 9 SUMMARY OF VERTIPORT DEVELOPMENT COSTS

Location	Cincinnati	Phoenix	Washington, D.C.	Mansfield	JFK
Type	Ground	Elevated	Elevated	Ground	Ground
TERMINAL ELEMENTS					
Buildings	0.00	$500,000	$126,775	$4,227,500	0.00
Fencing/Gates	46,500	5,500	0.00	155,500	0.00
Fuel System	$250,000	$250,000	$250,000	$300,000	0.00
Subtotal	$296,500	$755,500	$376,775	$4,683,000	$0
AIRSIDE ELEMENTS					
Pavement & Markings	$416,860	$152,000	$1,387,000	$3,284,800	$10,400
Lights/Electrical/Navaids	$233,840	$101,600	$156,800	$753,600	$416,850
Subtotal	**650,700**	**253,600**	**1,543,800**	**4,038,400**	**427,250**
SITE ELEMENTS					
Drainage/Erosion	0.00	0.00	0.00	$154,000	0.00
Grading & Filling	20,800	0.00	0.00	531,250	0.00
Utilities	0.00	0.00	$100,000	$300,000	0.00
Subtotal	**$20,800**	**$0**	**$100,000**	**$985,250**	**$0**
ADDITIONAL ITEMS					
ARFF	$50,000	$65,000	$60,000	$412,000	0.00
Snow & Ice Clearing	$50,000	0.00	$509,250	$50,000	0.00
Weather Equipment	$95,000	$95,000	$95,000	$108,100	0.00
Subtotal	**195,000**	**160,000**	**664,250**	**570,100**	**0**
TOTAL CONSTRUCTION COST	$1,163,000	$1,169,100	$2,684,825	$10,276,750	$427,250
Engineering & Contingency	$290,750	$292,275	$668,700	$2,569,190	$106,810
TOTAL COST	**1,453,750**	**1,461,375**	**3,353,525**	**12,845,940**	**534,060**

11.0 CONCLUSIONS AND RECOMMENDATIONS

An analysis of the data presented in this research report leads to a number of conclusions regarding the status of the design criteria for heliports and vertiports.

This section is divided into three parts. The first part focuses on facility design criteria as it relates to rotorcraft and CTR performance. The second part concentrates on issues that deal with application of the criteria to specific sites. The third and final section deals with recommendations for additional analysis and areas of study that need resolution.

11.1 HELIPORT AND VERTIPORT DESIGN CRITERIA

The primary concern regarding existing heliport design criteria is the balance of cost versus safety, and whether the so-called "target-level-of-safety" has been met by the existing design standards contained in the design AC. The debate focused on the strong sentiment of rotorcraft operators and industry representatives that existing heliport design criteria not be expanded, for several reasons:

a) Industry considers existing design criteria to be adequate, particularly for VFR facilities;

b) Expanding the size of either the physical facilities or airspace requirements might preclude some heliports from being constructed, particularly in urban areas; and

c) Although the FAA emphasizes the advisory nature of the criteria for privately owned heliports, the standards are typically adopted by state and local officials as part of their permitting requirements for any and all facilities.

On the other side of the debate, some concern has been expressed that existing design criteria may not provide the same margins of safety for public-use heliports, particularly those accommodating commercial operations, as do current airport design standards. Adding momentum to this debate, International Civil Aviation Organization (ICAO) recently adopted significantly more demanding heliport design criteria than FAA's. The same issues are relevant to vertiport design.

The conclusions drawn from this research effort are summarized as follows:

a) There is an extensive library of data and analysis, funded by FAA, focusing on rotorcraft performance as it relates to heliport design standards that are not reflected in the existing AC "Heliport Design." Those studies include, but are not limited to, reference 8, references 13 through 16, reference 21 and 26, and the following reports:

McConkey, Ed, et al, "Analysis of Helicopter Accident Risk Exposure Near Heliports, Airports, and Unimproved Sites," DOT/FAA/RD-90/9, Systems Control Technology, February 1992;

DeLucien, A.G., et al, "Study of Heliport Airspace and Real Estate Requirements," DOT/FAA/RD-80-107, PACER Systems, Inc., August 1980;

b) The AC "Heliport Design" does not contain requirements based on rotorcraft performance data, particularly takeoff, climb out, or landing requirement and limitations, nor any discussion regarding criteria necessary to meet Category A requirements. This is also true for "Vertiport Design."

c) The AC does not provide any information regarding operational capacity of a heliport other than a brief reference to multiple FATOs for utility heliports accommodating 10 or more operations per hour. Large public-use heliports or vertiports, particularly those that may accommodate scheduled service and/or high volumes of general aviation activity, need detailed guidelines and methodology to measure operational capacity. Those facilities need guidelines by which detailed facility recommendations can be made to accommodate various levels of activity, particularly under peak hour conditions, by specific classes and types of rotorcraft, operating VFR and IFR, with a variety of performance capabilities and limitations.

d) Several of the research studies prepared for the FAA noted that many rotorcraft flight manuals do not provide sufficient data for pilots to determine takeoff and climb performance under various density altitude and weight conditions.

   For example, if obstacles such as trees, power lines, etc. lie directly under the approach-departure route to a heliport, which just meet FAA's criteria of an 8:1 slope, pilots often cannot determine from the information in their Pilot Operating Handbook (POH) whether they can takeoff vertically and climb at an 8:1 slope under ambient conditions.

   The research reports proved that at density altitudes above sea level, many helicopters cannot perform vertical takeoff maneuvers and climb at 8:1 slopes, even when operating below maximum gross weight from heliports that meet FAA's design criteria. In addition, the height of the adjacent obstacles and their distance from the TLOF or FATO are often not available. Combined with the lack of data in POH's, pilots are often forced to "eyeball the situation," and base their go/no-go decision on the hover check just after lift-off.

e) Neither AC provides information about traffic pattern procedures to heliports, particularly high density areas, nor the impact on surrounding airspace from the development of a high activity heliport or vertiport. It is not possible, from the existing AC, to analyze or even recommend preferred traffic pattern procedures based on various types or classes of rotorcraft that will use the facility. In addition there is no information on how much airspace is required to accommodate such procedures, or how such procedures may impact existing airspace or air traffic patterns. Sources such as "Air Traffic Control," FAA

Order 7110.65H, as well as FAA's Airman's Information Manual, provide some guidance, however those documents are not referenced in the AC.

f) Because new technology aircraft, such as the CTR-22C, have not been certified by FAA it is not possible to say with certainty whether the performance characteristics described in this report are accurate. The certification of other aircraft with greater or lesser performance than the CTR-22C will affect vertiport design characteristics, particularly the size of the FATO/TLOF, as well as airspace requirements. As noted in this report, future aircraft performance may also be limited by FAA's certification process, which may impose performance restrictions and limitations not discussed in this report.

11.2 APPLICATION OF DESIGN CRITERIA TO SPECIFIC SITES

The following conclusions were drawn from the process of applying recommended design criteria to the specific sites:

a) The length of TLOF that is required has a significant effect on the feasibility of a site to accommodate the type and frequency of operations that would make a large heliport and vertiport viable. The Cincinnati, Ohio; Phoenix, Arizona; and Washington, D.C. sites had limited length TLOFs. The rooftop sites (Phoenix, Arizona and Washington, D.C.) can accommodate a 100 feet by 100 feet TLOF, which provides no acceleration areas or rollway capabilities at either site and no area for a rejected takeoff.

   Aircraft that operate at a facility with no rollway are limited to a vertical, rather than horizontal takeoff. During certain conditions, such as higher than standard temperature, humidity, and airfield elevation, these aircraft must operate at less than maximum gross weight. As a result, aircraft must operate at reduced payload, which limits the aircraft's financial viability, particularly for commercial operators. This is a serious limitation that should be avoided if at all possible.

   In addition, a minimum-sized TLOF forces aircraft operating under Category A to perform maneuvers that are not popular with pilots or passengers, such as climbing backwards in order to keep the landing site visible. They also provide no room for single-engine aircraft to perform emergency landings on-site in the event of a problem, such as an engine failure during takeoff.

b) Even a minimum sized FATO can have a substantial effect on the feasibility of a site to accommodate a vertiport. The FATO at the Cincinnati site, for example, extends over a city street as well as the access road to an architecturally important structure. Even if such a FATO did not impact the building or surrounding area structurally, local communities may object to heliport/vertiport operational areas extending beyond the limits of the facility.

c) The capacity and growth capability of a vertiport is greatly enhanced by additional TLOFs as long as: 1) multiple TLOFs allow independent operations, and 2) there is an adequate number of parking positions to equal the capacity of the TLOFs.

The capacity of a large heliport/vertiport can also be increased by use of an elongated TLOF with adequate exit taxiways (e.g., Mansfield, Texas and JFK International Airport, New York). As exhibited by the Phoenix, Arizona site, co-locating the CTR parking position with the TLOF significantly reduces the operational capacity of the heliport/vertiport. Actual operational experience with new CTR aircraft will be needed to determine what aircraft separation, TLOF occupancy, and gate turnaround times will be required.

d) A full-service large heliport/vertiport may not be feasible at city-center or urban areas. There is not sufficient area at the Cincinnati, Phoenix or Washington, D.C. sites to accommodate hangars, apron parking, maintenance areas, or cargo areas, even if all of the non-operational facilities (terminal building, auto parking, equipment storage, etc.), are placed on a floor below the heliport/vertiport. Even unique sites such as the new Dallas vertiport, with its very large operational areas, do not have full aircraft maintenance and hangar storage facilities.

Full-service facilities on-airport sites (JFK International Airport, New York) appear feasible where many of the facilities already exist and are available for CTR use. Suburban areas (Mansfield, Texas) would likely have the space to accommodate a full-service vertiport.

e) Full passenger services appear feasible at most sites including rooftop facilities if there is sufficient area for terminal, security, rental car, auto parking facilities, etc., on the floors below the heliport/vertiport.

f) Fuel service appears feasible at ground-level heliports/vertiports. Fuel service at rooftop facilities requires additional safety controls (per NFPA), design criteria (such as separate drainage systems), and higher costs, and in some cases may not be allowed by local land use and/or building code restrictions.

g) Many of the sites selected for analysis in this report are very poor locations for public vertiports. The limited area available for the FATO and the inability to commission instrument procedures would each be a serious and probably fatal flaw. The limited area available for aircraft parking areas (gates) is also a very serious shortcoming.

h) In the analysis of the recent vertiport feasibility studies (reference 32), the generally accepted wisdom was that the business traveler is the predominate CTR passenger. This report also makes this assumption. However, in other studies performed for the FAA by the Volpe National Transportation System Center, analysis indicates that only two thirds of CTR passengers will be business

travelers. The remainder will be leisure travelers. (These are national averages and vary from region to region.) Due to the effect that such assumptions have on vertiport design, this is an issue that needs to be carefully considered before undertaking the design of a specific facility.

11.3 RECOMMENDATIONS

The recommendations discussed below have been developed based on the conclusions presented in the previous sections:

a) Compile data from the numerous research reports sponsored by FAA regarding rotorcraft performance characteristics by different classes of rotorcraft. Specifically, the issue of RTO and category A requirements, as well as climb capabilities under various ambient conditions, should be presented in the AC. Also the dimensions of a heliport/vertiport maneuver/acceleration area (rollway) and its size as a function of aircraft performance capabilities and density altitude needs to be presented, similar to runway length curves in the airport design ACs.

b) Undertake a detailed capacity analysis and develop a heliport/vertiport capacity handbook and computer model that provides specific guidelines for the location, number, and size of facilities such as TLOFs, FATOs, taxiways, taxilanes, and rotorcraft parking positions. Specific considerations should be given to separation requirements to accommodate rotorwash (wake turbulence) for approach and departure procedures, as well as ground maneuvering.

   Particular attention should be given to the issues of rotorwash and vertiport capacity as they affect parking area (gate) separation. There is a vertiport design tradeoff affecting safety, capacity, and land requirements (gate separations). When maximum capacity is needed, it will be desirable/required for CTR at adjacent gates to operate independently. Thus, a CTR could be taxiing in or out while passengers were loading/unloading at an adjacent gate. (There is also discussion in the CTRDAC about the possibility that the CTR would not shut down its engines while loading and unloading. And, since the CTR rotor blades are high twist blades, it would not be possible to operate them at "flat pitch.") Smaller gate separations could be safely accepted if operations at adjacent gates were restricted (with a resultant loss of capacity). Another option is to implement something like loading bridges ("jetways") to protect passengers from rotorwash during loading/unloading.

c) Develop detailed traffic pattern procedures for public-use vertiports/heliports for both VFR and IFR conditions. Although the military and some large civil helicopter companies operate heliports with high volumes of traffic, they represent a different situation than is typically encountered at public-use heliports. Those facilities are operated by agencies and companies that also directly control pilot hiring and training requirements, so that they can ensure pilots using those facilities are trained to specific levels of competence. At

public-use heliports, no such "quality controls" are available. While these large operators provide useful information based on their experience, specific procedures similar to those contained in Federal regulations that require mandatory certificates, ratings, or authorization need to be developed.

d) Develop standard techniques for analyzing airspace impacts from rotorcraft operations at high density vertiports/heliports. This needs to be done for stand-alone vertiports/heliports and vertiports/heliports on airports. Standard techniques need to be developed in order to provide guidelines for assessing impacts on local and regional airspace if controlled airspace is instituted around vertiports/heliports. Also, criteria for the establishment and operation of control towers (Class D airspace) at vertiports/heliports needs to be developed.

   Many urban heliports underlie existing Class B and Class C airspace, and guidelines for implementing Class D or E airspace at vertiports/heliports underlying already existing controlled airspace need to be promulgated.

e) Review or study actual operating characteristics of CTRs to establish minimum TLOF and FATO length requirements. Particular attention must be given to operations in the event of a single-engine failure.

f) Review or study actual operating characteristics of CTRs to determine accurate imaginary surface requirements. Required FATO size and approach surface size and slope substantially affect the feasibility of locating a vertiport at a given site.

g) Determine actual TLOF and gate occupancy characteristics and the resultant impact on capacity. This study should include the observation of TLOF occupancy time, taxiing time to gate, aircraft servicing times, and passenger enplaning/deplaning times. The result would allow a more accurate estimate of TLOF and gate capacity.

h) Evaluate data from military CTRs when available to assess operational characteristics of the military aircraft in civilian-type missions (cargo, passenger transport, passenger boarding/disembarking, etc.).

i) Determine the full impact of both FAR Parts 107 and 139 on vertiport management, facility layout, design, and economic feasibility. The possible operational and economic implications at vertiports to meet these regulations needs to be investigated as CTRs are expected to develop a 30 or more passenger capacity.

j) Modify 14 CFR 77 to include reference to vertiports. Modify 14 CFR 77 to include reference to IFR airspace for both vertiports and heliports.

11.4 LOOKING TOWARD THE FUTURE

The subjects of vertiports and tiltrotor are currently in rapid transition. Several ongoing efforts are bringing about significant changes in thinking.

The first of these involves the work of the Congressionally mandated Civil Tiltrotor Development Advisory Committee (CTRDAC) and its four subcommittees. The work of the Environment/Safety Subcommittee has shown that the L_{dn} 65 dB noise footprint for a given daily number of CTR approaches and departures will cover 120 to 130 acres. Environmental spokespersons have questioned the applicability of the L_{dn} metric to low-frequency rotorcraft noise and the adequacy the L_{dn} 65 dB contour line. The work of the Economics and Infrastructure Subcommittees has shown that capacity requirements will dictate the need for multiple TLOF's and multiple gates at public-use facilities. The Environmental/Safety and Aircraft subcommittees have pointed the way toward a CTR that is 12 dB quieter than the V-22. These are just a few of the CTRDAC's findings that will influence the eventual design and operation of CTR and vertiports.

The second of these efforts involves the work of the manufacturers. Choosing to build a CTR has been touted as a $1.2 billion decision. The manufacturers are looking toward risk reduction research and a demonstration aircraft to help them make this decision. The CTR will be a substantially different aircraft than the V-22. But to date, this CTR has not yet even been designed. Boeing has proposed a 40-passenger CTR2000 aircraft but, at this point, it is only a design concept. The first operational CTR could be significantly different than the CTR2000. It might even be a 9-passenger aircraft.

The third of these efforts involves the work of the FAA in developing GPS TERPS for rotorcraft. Data collection for the development of rotorcraft nonprecision approach TERPS was completed in November 1994. Data collection for rotorcraft Category 1 precision approach TERPS is scheduled to start in the summer of 1996. Detailed planning for rotorcraft Category 2 and 3 precision approach TERPS has not yet been completed. GPS is far superior to MLS for heliports and vertiports. Both the increase in accuracy and the decrease in cost are powerful improvements. Rotorcraft GPS TERPS airspace is likely to be somewhat smaller than what was proposed for collocated MLS TERPS.

In 1987, the FAA took aggressive action to start preparing for the implementation of CTR operations. Looking back to the thinking of that time; concepts of CTR design, vertiport design, and CTR operation now look naive and simplistic. Tremendous evolution has already taken place in this thinking and much more is currently in process. CTR promises significant national benefits in terms of aviation capacity and/or decreases in congestion and delay. Much design and planning remains to be done to bring this about.

LIST OF ACRONYMS

A&P	Airframe and Powerplant
AC	Advisory Circular
ACM	Airport Certification Manual
ACS	Airport Certification Specifications
ADG	Airplane Design Group
AEP	Airport Emergency Plan
AFFF	Aqueous Film Forming Foam
AGL	Above Ground Level
AIM	Aeronautical Information Manual
AIP	Airport Improvement Program
ALPA	Airline Pilots Association
ARC	Airport Reference Code
ARFF	Aircraft Rescue and Firefighting
ASOS	Automated Surface Observation System (National Weather Service)
ASV	Annual Service Volume
ATC	Air Traffic Control
ATO	Airline Ticket Office
A(V)EP	Airport (Vertiport) Emergency Plan
AVF	Advanced Vertical Flight
AWOS	Automated Weather Observing System
CDP	Critical Decision Point
CF	Cubic Feet
CFR	Code of Federal Regulations
CTR	Civil Tiltrotor
CTRDAC	Civil Tiltrotor Development Advisory Committee
CY	Cubic Yards
dB	Decibels
DME	Distance Measuring Equipment
DCP	Data Collection Package(s) (associated with ASOS)
DFW	Dallas-Fort Worth Airport
dGPS	Differential Global Positioning System
DH	Decision Height
EPA	Environmental Protection Agency
EUROFAR	European Future Advanced Rotorcraft
F	Fahrenheit
FAA	Federal Aviation Administration
FAC	Final Approach Course
FAR	Federal Aviation Regulation
FARA	Final Approach Reference Area
FATO	Final Approach and Takeoff Area
FE	Field Elevation
GA	General Aviation
GIS	Geographic Information System
gpm	Gallons Per Minute

GPS	Global Positioning System
HADR	Heliport Acceleration Distance Required
HALS	Heliport Approach Lighting System
HAZMAT	Hazardous Materials
HIGE	Hover in Ground Effect
HILS	Heliport Instrument Lighting System
HMA	Heliport Maneuver Area
HNM	Helicopter Noise Model
HOGE	Hover Out of Ground Effect
HV	Height Velocity
HVAC	Heating, Ventilation, and Air Conditioning
IAP	Instrument Approach Procedure
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IGE	In Ground Effect
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INM	Integrated Noise Model
JFK	John F. Kennedy International Airport
L_{dn}	Day-Night Average Sound Level
LF	Linear Foot
LS	Lump Sum
MAP	Missed Approach Point
MD	McDonnell Douglas Aircraft Company
MGTOW	Maximum Gross Takeoff Weight
MITL	Medium Intensity Taxiway Edge Lights
MLS	Microwave Landing System
MPH	Miles Per Hour
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NASTO	National Association of State Transportation Officials
NDB	Non-directional Beacon
NFPA	National Fire Protection Association
NLR	Noise Level Reduction
NPIAS	National Plan of Integrated Airport Systems
NWS	National Weather Service
OEI	One Engine Inoperative
PANYNJ	Port Authority of New York and New Jersey
PAPI	Precision Approach Path Indicator
PCC	Portland Cement Concrete
PFA	Practical Fire Area
POH	Pilot Operating Handbook
PSI	Pounds per Square Inch
R&D	Research and Development
RPM	Revolutions Per Minute

RTO	Rejected Takeoff
RVR	Runway Visual Range
SAO	Surface Aviation Observation
sf	Square Feet
SRE	Snow Removal Equipment
STOL	Short Takeoff and Landing
SY	Square Yard
TERPS	Terminal Instrument Procedures
TFPM	Terminal Facilities Programming Model
TLOF	Touchdown and Lift-off Surface
TRACON	Terminal Radar Approach Control
UNICOM	Universal Communication
USGS	United States Geological Survey
VASI	Visual Approach Slope Indicator
VFPO	Vertical Flight Program Office
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omni-directional Range
VTOL	Vertical Takeoff and Landing
VZ	Vertiport Zone

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3. Civil Tiltrotor Development Advisory Committee Report to Congress in accordance with PL102-581, December 1995.

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16. McConkey E., Anoll R., Renton M., and Young J., "Helicopter Physical and Performance Data," DOT/FAA/RD-90/3, SAIC (formerly Systems Control Technology) for the Federal Aviation Administration, August 1991.

17. Anoll R. and McConkey E., "Rotorcraft Acceleration and Climb Performance Model," DOT/FAA/RD-90/6, SAIC (formerly Systems Control Technology) for the Federal Aviation Administration, August 1991.

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APPENDIX A. FAA ADVISORY CIRCULAR SYSTEM

FAA advisory circulars (ACs) are numbered by subject areas that correspond to the pertinent Federal Aviation Regulations (FARs). The series of advisory circulars dealing with airport planning, design, and construction are covered by subject number 150, which encompasses over 100 separate ACs. The ACs in subject area 150 - Airports are further organized into six broad categories:

- Airport Planning,
- Federal-Aid Airport Programs,
- Surplus Airport Property Conveyance Programs,
- Airport Compliance Programs,
- Airport Safety - General, and
- Design, Construction, and Maintenance - General.

Some of the specific ACs dealing with airport design that impact large heliports and vertiports include, but are not limited to:

- Noise Control and Compatibility Planning for Airports, 150/5020-1, 8-5-83;
- Planning the State Aviation System, 150/5050-3B, 1-6-89;
- The Continuous Airport System Planning Process, 150/5050-5, 11-28-75;
- Airport Capacity and Delay, 150/5060-5, 9-23-83;
- Planning the Metropolitan Airport System, 150/5070-5, 5-22-70;
- Airport Master Plans, 150/5070-6A, 6-85;
- A Model Zoning Ordinance to Limit Height of Objects Around Airports, 150/5190-4A, 12-87; and
- Planning and Design of Airport Terminal Facilities at Non-Hub Locations, 150/5360-9, 4-80.

This is not intended to be an exhaustive list of all appropriate ACs. Examination of all of the ACs within subject area 150 highlights the fact that the amount of design criteria promulgated for airports is significantly greater than for heliports and vertiports. Under the category of design, construction, and maintenance - general, only two ACs specifically deal with heliport and vertiport design:

- Heliport Design, 150/5390-2A, 1/20/94; and
- Vertiport Design, 150/5390-3, 5/31/91.

The FAA incorporates the information contained in the many ACs in the airport subject area (over 150), as well as other ACs, orders, regulations, and outside sources, by reference. For example, within AC 150/5390-2A, Heliport Design, the following ACs, FARs, and orders are specifically referenced as factors to be considered in the design and planning of heliports even though they were originally developed for airports:

- FAR Part 77, Objects Affecting Navigable Airspace;
- FAR Part 157, Notice of Construction, Alteration, Activation and Deactivation of Airports;
- FAA Order 5050.4A, Airport Environmental Handbook;
- National Fire Protection Association (NFPA) Pamphlet 418, Roof-Top Heliports;
- AC 20-35, Tiedown Sense;
- AC 70/7460-1, Obstruction Lighting and Marking;
- AC 70/7460-2, Proposed Construction or Alteration of Objects Affecting Navigable Airspace;
- AC 150/5230-4, Aircraft Fuel Storage, Handling, and Dispensing on Airports;
- AC 150/5340-19, Taxiway Centerline Lighting Systems;
- AC 150/5345-46, Specifications for Runway and Taxiway Light Fixtures; and
- AC 150/5360-9, Planning and Design of Airport Terminal Facilities at Non-Hub Locations.

This system of incorporating design standards by reference to other sources (such as FARs, ACs, orders, etc.) is commonly used by for FAA, because it accomplishes the objectives described in the following paragraphs.

a) It allows an essentially unlimited number of standards and criteria contained in a variety of sources to be incorporated as the need arises, providing flexibility when establishing or revising appropriate design criteria. It is much easier administratively to update, revise, or cancel an AC than it is a regulation or an order. That can be seen, for example, in the Vertiport Design Guide, which makes reference to FAR Part 77 in terms of imaginary surfaces, although Part 77 in fact has no reference to vertiports.

b) Much of the design criteria (such as the specifications for wind cones and lighting fixtures) can be updated and revised without changing the basic AC. For example, when the specifications for airfield lighting are updated, the airport, heliport, and vertiport ACs do not need to be updated as a consequence of that change since they incorporate the most current lighting standards by reference.

c) All of the elements of airport design standards that are appropriate to heliports and vertiports can be incorporated and utilized, thereby eliminating unnecessary duplication of standards.

ACs are just that, advisory, until an airport/heliport sponsor receives a grant from the FAA. Any Federally-funded project, or any project on a Federally-funded airport/heliport must be designed in compliance with appropriate AC criteria and standards. The ACs represent minimum design standards, and an airport can be designed to higher standards if they so desire, although there is no guarantee that the FAA will fund the additional cost of meeting the higher design standards.

APPENDIX B. 14 CFR 139: CERTIFICATION AND OPERATION: AIRPORTS SERVING CAB CERTIFICATED AIR CARRIERS and 14 CFR 107: AIRPORT SECURITY

INTRODUCTION

Federal Aviation Regulation Part 139, "Certification And Operations: Land Airports Serving Certificated Air Carriers," prescribes requirements for certification and operation of land airports which serve scheduled or unscheduled air carrier passenger aircraft with seating capacity of more than 30 passengers. Because there are currently no heliports or vertiports that provided regularly scheduled passenger service, FAA Part 139 applies only to fixed-wing facilities. However, it is anticipated that when heliports and vertiports begin accommodating scheduled AVF aircraft service, FAR Part 139 will be applied. FAR Part 139 has a significant impact on airport management, as well as some facility layout and design criteria. It is very possible that FAR Part 139 will be revised in the future, so that some of the information presented below will be changed by the time it would be applicable to vertiports.

Under FAR Part 139, an airport (or vertiport or large heliport) serving scheduled air carriers with passenger seating of 30 or more is required to operate under an operating certificate, and an airport serving unscheduled air carriers is required to operate under at least a limited operating certificate. Preparation of an Airport Certification Manual (ACM) is required for compliance with operating certificate requirements, and Airport Certification Specifications (ACS) are required for compliance with limited operating certificate requirements. More compliance items are required in the ACM than are required in the ACS. Guidance for preparation of the ACM or ACS is contained in FAA AC 139 201-1, "ACM & ACS." The following analysis describes what measures or facilities would be required at the vertiport to comply with Part 139 requirements for an operating certificate versus a limited certificate.

Part 139 is comprised of the four subparts:

Subpart A - General - Subpart A prescribes the rules governing certification and operation of airports which serve any operations by scheduled or unscheduled air carriers using aircraft with more than 30 seats (such as a CTR-22C, EH-101, or S-92).

Subpart B - Certification - Subpart B prescribes the certification requirements authority of the FAA to inspect the airport for compliance with Part 139, duration of the operating certificate, and exemptions and deviations. There is an important difference between exemptions and deviations. Exemptions to certain Part 139 requirements are obtained by petitioning the FAA, and if obtained, do not require the airport to be in compliance with that requirement. In emergency conditions requiring immediate action for the protection of life or property, the certificate holder may deviate from any requirement of Subpart D to the extent required to meet the emergency. This means that the intent of the subpart must be followed, but in

certain emergency situations, the airport may deviate from certain specific requirements of Subpart D.

Subpart C - ACM and ACS - Subpart C prescribes the content and processing procedures for the ACM and ACS.

Subpart D - Operations - Subpart D of Part 139 includes 22 subsections which prescribe requirements or criteria for personnel, paved areas, aircraft rescue and firefighting, ground vehicles, etc.

Subpart D requirements apply only to those movement areas, safety areas, and lighting systems on a vertiport that are, or will be, used by air carrier aircraft. Movement areas as defined in Part 139.3 include runways (TLOFs and FATOs), taxiways, and other areas on the airport that are used for taxiing, takeoff, or landing of aircraft. Movement areas do not include aprons or aircraft parking areas.

Part 139.301 Inspection Authority

Each certificate holder must allow the FAA to conduct inspections, at times unannounced, to determine an airport's compliance with Subpart D. Sponsors can be fined or have their operating certificate revoked for violations of Part 139 discovered as a result of the inspection.

Part 139.303 Personnel

Each certificate holder must maintain sufficient qualified personnel to comply with Subpart D. There is no specific list of personnel required; however, the following are typically the minimum personnel needed at a non- or small-hub vertiport:

- vertiport manager,
- director of operations/assistant manager,
- fire chief/emergency response director,
- firefighting staff,
- director of maintenance, and
- maintenance staff.

Some of the functions can be combined into fewer positions depending on volume of passenger enplanements, aircraft operations, the number of different airlines serving the airport, and physical size of the facility.

Part 139.305 Paved Areas

All pavement in designated movement areas must be maintained in good condition and meet all requirements specified in appropriate advisory circulars.

Part 139.309 Safety Areas

Runway (FATO) and taxiway safety areas must be maintained according to the standards prescribed in FAA ACs 150/5390-3 and -2A. Taxiways that may be used by Part 139 air carrier aircraft should have 118 foot wide safety areas.

Part 139.311 Marking And Lighting

Criteria for the marking of paved areas at vertiports and large heliports is contained in appropriate ACs and must be maintained to those standards. The lighting requirements specified in FAA Order 8260.3B, "Terminal Instrument Procedures (TERPS)," must also be met and fully maintained. Obstruction lighting and removal requirements are discussed in section Part 139.331 "Obstructions."

Part 139.313 Snow And Ice Control

FAR Part 139.313 requires that a certificate holder prepare and implement a snow and ice control plan. The snow and ice control plan includes instructions and procedures for removal of snow and ice from primary aircraft movement surfaces, selection of approved snow and ice removal materials, timely commencement of removal operations, and prompt notification of all air carriers when snow and ice on a movement area is less than satisfactory.

Snow and ice control requirements are described in FAA AC 150/5200-30A, "Airport Winter Safety and Operations." Per the AC, at a commercial airport with 10,000 to 40,000 annual aircraft operations, sufficient personnel and equipment should be provided to remove 1 inch of snow weighing up to 25 pounds/cubic foot in all primary movement areas within 1 hour.

Part 139.315 Aircraft Rescue And Firefighting: Index Determination

The determination of an index relating to aircraft rescue and firefighting (ARFF) capabilities is based on the longest aircraft conducting at least five departures per day. All proposed CTR aircraft and large helicopters (EH-101 and S-92) are less than 90 feet in length, so Index A requirements would apply. Index A is the lowest ARFF index in Part 139.

Part 139.317 Aircraft Rescue And Firefighting: Equipment And Agents

Part 139.317 describes the minimum equipment and agents for Index A vertiports.

One firefighting vehicle is required carrying at least:

a) 500 pounds of sodium-based dry chemical or halon 1211, with a discharge rate of 5 pounds/second through a hand line or 16 pounds/second through a turret, or,

b) 450 pounds of potassium-based dry chemical discharged at a rate of 5 pounds/second, and

c) water with a commensurate quantity of aqueous film forming foam (AFFF) to total 100 gallons, for simultaneous dry chemical and AFFF application.

A discharge rate for AFFF for Index A is not included in Part 139. The National Fire Protection Association (NFPA) publication 414, "Standard For Aircraft Rescue And Fire Fighting Vehicles" provides guidance for minimum quantities of agent and discharge rates. NFPA 414 shows that for Index A activity, AFFF should be discharged at a minimum rate of 390 gallons per minute (gpm).

Protein or fluoroprotein foam, if substituted for AFFF, should be discharged at a minimum rate of 530 or 575 gpm, respectively. Part 139 also requires that twice the quantity of AFFF to be mixed with the required amount of water be carried on the response vehicle as well. Additionally, FAA AC 150/5210-6C, "Aircraft Fire And Rescue Facilities And Extinguishing Agents," states that for operating and training purposes, twice the quantities that are required to be carried on the response vehicle(s) should be stored in proximity to the airport fire station. Minimum ARFF equipment and extinguishing agents include one ARFF vehicle with capabilities discussed above, and sufficient area to store extinguishing agents that are on hand.

Dimensions of Index A response vehicles are included in FAA AC 150/5210-15, "Airport Rescue and Fire Fighting Station Building Design." Index A response vehicles are from 6 feet to 8 feet wide, 18 feet to 20 feet long, and 7 feet to 10 feet high. Minimum clearances that would apply to these vehicles are likely to increase real estate requirements for the vertical flight facility. For example, the AC mentioned 6 feet between the response vehicle and walls or storage areas, 8 feet between parked vehicles and the response vehicle parked side to side, 5 feet in front and in back of the response vehicle, and 7 feet above the response vehicle. Minimum bay door dimensions are 14 feet wide and 15 feet high. One to two crew members are required to staff the Index A response vehicle. In addition to agent storage, an area of 4 square feet per firefighter is required for gear storage. Additional required functional areas in the fire station for Index A include a combination watch/alarm room and fire department office space of 100 square feet. If response agents

are stored in the fire station, there must be sufficient area to store at least twice the amount of agent carried on the response vehicle.

FAA AC 150/5220-4A, "Water Supply System For Aircraft Fire And Rescue Protection," provides that whenever possible, water service at a vertiport should be sufficient to fill water in response vehicles in 2 minutes at a pressure of 80 psi. Assuming a 200-gallon water tank capacity, the required water service flow rate would be at least 100 gallons per minute. A 300-gallon water capacity on the response vehicle would require a water flow rate of 150 gpm. There is a 42-gallon cold water storage tank and pump in the existing ARFF/snow removal equipment (SRE) building. Additional water storage capacity and fire service pumps would be required to maintain required pressure and quantity of water.

Minimum dimensions of the response vehicle bay would be 20 feet wide by 33 feet long. A 6- to 10 foot wide area along the side of the station would be adequate for office and storage areas. Descriptions of equipment to be carried on the response vehicle or that can be transported to the scene at the same time as the response vehicle are included in FAA AC 150/5210-6C and NFPA 403, "Aircraft Rescue And Firefighting Services At Airports."

FAR Part 139.325 "Airport Emergency Plan" requires that certificated airports include provisions for rescue of aircraft accident victims from "significant bodies of water" in their emergency plan. "Significant bodies of water" per Part 139 include any bodies of water more than 1/4 square mile in area which cannot be traversed by conventional vehicles. FAA AC 150/5210-13A further refines the definition of "significant bodies of water" as water bodies having an area of more than 1/4 square mile within 2 miles of an airport runway.

Boats of various sizes are used as the primary response vessel in marine incidents related to airports (and vertiports). Part 139 requires that the water rescue plan must provide for rescue vessels with a combined capacity equal to or greater than the maximum number of passengers that can be carried aboard the largest aircraft. CTR-22C aircraft would require response vessels to have a combined capacity of 40 people (to include crew and passengers). Typically a 16 foot to 22 foot long response boat is the primary response vessel. Carried aboard the primary response vessel would be a sufficient number of life rafts, which when combined with the primary response vessel, would be able to accommodate 40 to 50 people. Two 25-person life rafts carried aboard the primary response vessel would be adequate. Appropriate medical and additional rescue equipment should be carried aboard the response vessel as well.

The response vessel should not be permanently moored in the water due to the chance of damage from winds and icing conditions. It should be housed in a garage facility on a trailer that can be quickly transported to the shore. Appropriate response equipment should be stored on the response vessel as well as in the garage. A suitable vehicle should be in close proximity to the response vessel garage to tow the response vessel on the trailer to the shore.

The list of equipment recommended by the National Fire Protection Association (NFPA) and the FAA (through FAA AC 150/5220-10A, "Guide Specification For Water/Foam Aircraft Rescue And Firefighting Vehicles") should be carried on an Index A response truck. A list of equipment that is typically included in an airport rescue and firefighting station is also included in FAA AC 150/5210-5. The equipment actually carried on the response vehicle and located in the fire station varies widely from airport to airport. The cost estimates shown are for a conceptual Index A commercial service vertiport and are based on recent prices obtained from a similarly equipped airport. They are not intended to be used for actual cost estimating, grant applications, or budgeting purposes at any specific facility, but merely provided as a level of cost that may be incurred to comply with certain, but not all, requirements of 14 CFR 139.

COST ESTIMATE OF EQUIPMENT FOR Part 139 ARFF AND MARINE RESPONSE CAPABILITY

I. Primary Index A response truck -	$175,000-$195,000
equipment to be carried on the truck & other equipment associated with the primary response truck -	$15,000-$30,000
General purpose pickup truck -	$17,000
Subtotal -	$207,000-$242,000
II. Fire station -	$100,000 to $150,000
Equipment for the fire station -	$50,000
Subtotal -	$150,000 to $200,000
III. Marine response vessel including trailer, portable fire pump and other equipment -	$30,000
Two 25-person inflatable life rafts -	$500
Heated garage for response boat -	$30,000
Subtotal -	$60,500
Total -	$417,500 to $502,500

Source: Hoyle, Tanner & Associates, Inc.

Part 139.319 Aircraft Rescue And Firefighting: Operational Requirements

Part 139 requires a maximum response time of 3 minutes from the time the alarm sounds for the first response vehicle to reach the midpoint of the farthest air carrier runway (FATO) and begin to dispense agent, and 4 minutes for all other required vehicles to reach the same point and respond. NFPA 403 requires that the first response vehicle reach any point on the operational runway within 2 minutes of the alarm and reach the rapid response area (500 feet either side and 1,600 feet beyond each runway end) within 2.5 minutes. As discussed previously, only one airfield ARFF response vehicle is required for Index A facilities.

Part 139 requires that personnel available for ARFF response be trained according to specific guidelines, including participation in at least one live fire drill every 12 months, and that at least one ARFF response person be given at least 40 hours of training in basic emergency medical care. Basic emergency care includes treatment of bleeding; shock; injuries to the skull, spine, chest, and extremities; treatment of internal injuries and burns; and providing triage, primary patient survey, and cardiopulmonary resuscitation (CPR).

As one to two persons are required to staff the ARFF vehicle, the ARFF staff at the airport during a shift should be a minimum of two people. Some airports have permanent ARFF staff while other airports use firefighters on a part-time basis from local fire departments. Using staff from local fire departments reduces costs to the airport. Assuming Part 139 air carrier flights in the morning, noon to early afternoon, evening, and possibly nighttime, the ARFF function would have to be staffed 16 hours per day (approximately 6:00 am to 10:00 pm).

Firefighters may be assigned other duties at the vertiport when they are not needed for ARFF. Such duties may include security, monitoring/recording airport operations, or maintenance. An appropriate staffing level may include two firefighters on two 8-hour shifts per day, and a team of two more firefighters for weekend work and to supplement firefighters on other shifts. Total staffing requirements would be six firefighters and one fire chief. The ARFF staffing level described would be sufficient to include coverage of water rescue responsibilities as well.

For planning purposes, an annual labor cost of $30,000 is assumed for each of the four firefighters, $5,000 for each of the two firefighters on the supplemental crew, and $45,000 for the fire chief. Labor costs include costs of all wages and benefits. Total annual labor costs is approximately $175,000. If the fire fighters are cross-utilized, the ARFF labor cost to the airport could be substantially reduced. Training for all firefighters at other Index A airports costs approximately $2,000 per person, per year. Other annual ARFF costs at various airports include $4,000 for equipment and supplies, $1,500 per year for agent refill, and $800 to $1,000 for maintenance of equipment.

Part 139.321 Handling And Storage Of Hazardous Substances

FAA AC 139.201-1, "ACM & ACS," discusses two types of cargo related to Part 139.321, hazardous materials (HAZMAT) such as hazardous aircraft cargo and hazardous materials in the form of fuels, lubricants, etc. (fuels). If HAZMAT is transported to or from the vertiport by an entity other than the airport, hazardous materials regulations for the transporter would apply. If the airport transports HAZMAT, measures for dealing with HAZMAT cleanup should be included in the Airport Emergency Manual. Part 139 requires preparation of minimum standards relating to fuel handling and requires that fuel handlers be trained according to a specific program. A certificated vertiport must obtain certification from the fueling agent (such as the fixed base operator (FBO)) that such required training has been accomplished.

Part 139.323 Traffic And Wind Indicators

Per Part 139, the vertiport must have a lighted wind cone. If the vertiport does not have a standard traffic pattern or a control tower, it must also have a segmented circle with traffic pattern indicators for each runway (FATO). VFR traffic patterns to uncontrolled vertiports and heliports have not been established; however, standardized procedures for high activity facilities should be developed.

Part 139.325 Vertiport Emergency Plan

Part 139 requires that each airport (vertiport) sponsor prepare a Airport (Vertiport) Emergency Plan (A(V)EP) as a prerequisite to Part 139 certification. FAA AC 150/5200-31, "Airport Emergency Plan," (AEP) includes guidance on preparation of an AEP. By extrapolating from this document, the A(V)EP must contain instructions for response to:

- aircraft incidents and accidents;
- bomb incidents, including designated parking areas for the aircraft involved;
- structural fires;
- natural disasters;
- radiological incidents;
- sabotage, hijacking, and other unlawful interference with airport operations;
- failure of power for lighting in the movement area; and
- water rescue situations, if applicable.

The A(V)EP must also address or include:

- provision of medical services to the maximum number of persons expected to be carried on the largest air carrier aircraft expected to serve the airport;

- names, addresses, telephone numbers, etc., of hospitals and other facilities and persons at the airport or in the airport area that have agreed to provide medical assistance;

- an inventory of equipment committed to use for airport incidents or emergencies;

- each building, hangar, etc., on or off the airport that will be used to accommodate uninjured, injured, and deceased persons; and

- crowd control and security.

Each Part 139 certificate holder is required to:

- coordinate with law enforcement agencies, fire fighting agencies, medical personnel, etc., who have responsibilities under the A(V)EP;

- provide for participation by all law enforcement agencies, fire fighting agencies, medical personnel, etc., who have responsibilities under the A(V)EP;

- ensure that all airport personnel having responsibilities under the A(V)EP are properly trained;

- review the A(V)EP with all concerned parties at least once every 12 months; and

- hold a full-scale A(V)EP exercise at least once every 3 years.

FAA AC 150/5210-2A, "Airport Emergency Medical Facilities and Services," lists general guidelines for such facilities and services that should be provided at airports (and vertiports) related to Airport Index. Airport Index for these purposes is based on the frequency of use of the airport and the size of the aircraft at the airport. The typical Airport Index for vertiports and large heliports would be Index 4, serving transport aircraft operations exceeding 2,800 annual movements with en route segments of less than 200 miles. The next lower index is Index 3, which pertains to airports serving single-engine aircraft seating 5 or more and/or twin-engine aircraft grossing under 12,500 pounds with annual movements of 10,000 or more.

FAA AC 150/5210-2A recommends that a first aid room of approximately 7 feet to 8 feet wide and 10 feet long should be adequate for Airport Index 4. Equipment to be provided in a first aid room, as well as all other first aid capabilities at a specific airport, should be determined by a medical professional in the local area well-versed in first aid and emergency response. Note that Part 139.319 requires that personnel available for ARFF response be given at least 40 hours of training in basic emergency medical care. Preparation of an A(V)EP requires substantial time to coordinate with and obtain commitment from all appropriate persons and agencies. A draft A(V)EP is prepared, reviewed, and may be tested in a "table top exercise." A table top exercise includes appropriate persons and agencies in an office around an aerial photo of the vertiport and surrounding area rehearsing what each would do in the event of an emergency. The A(V)EP must provide for staging of mock emergencies at the airport to periodically test the effectiveness of the AEP. Preparation of an A(V)EP can cost $10,000 to $15,000 or more.

Part 139.327 Self-Inspection Program

Part 139 certificated airports are required to prepare and carry out an airport self-inspection plan. Inspections are required daily; are also required during unusual situations such as meteorological conditions that may affect air carrier operations; and are required

immediately after an accident or incident. Airports (vertiports) are required to maintain inspection reports for a period of at least 6 months. Part 139 requires that qualified personnel conduct the inspections. FAA AC 150/5200-18B, "Airport Safety Self-Inspection," includes standards for conducting airport self-inspections and describes four types of inspections.

- Regularly scheduled inspections - daily inspection of all pavement areas, safety areas, markings and signs, lighting, navigational aids, obstructions, fueling operations, snow and ice conditions, construction, aircraft rescue and firefighting, public protection, and wildlife hazard management.

- Continuous surveillance - general inspection for compliance with regulations and procedures relating to ground vehicles, fueling operations, snow and ice control, construction, public protection, wildlife hazard management, pedestrian access to movement areas, passenger loading and unloading areas, other movement areas, and debris in movement areas when airport staff are in the operations area.

- Periodic condition evaluation - specific checks of physical facilities on a regular, but less frequent schedule than the regularly scheduled inspections. Periodic condition evaluations pertain to pavement areas, markings and signs, lighting, navigational aids, obstructions, fueling operations, and aircraft rescue and firefighting.

- Special inspection - inspections done after receipt of a complaint or as triggered by an unusual condition or event relating to pavement areas, safety areas, markings and signs, snow and ice, and construction.

Sample checklists for each of the four types of inspections are included in FAA AC 150/5200-18B. Existing airport (vertiport) staff can be used for the self-inspection program.

Part 139.329 Ground Vehicles

Part 139 requires that access to movement areas be limited to only those ground vehicles necessary for airport operations, that procedures be developed for operation of ground vehicles in movement areas, and that operators of ground vehicles in the movement areas be familiar with airport procedures. The airport must also have suitable control of ground vehicles with existing fencing and restricted access gates. A plan should be developed for control of ground vehicles. The airport staff, or law enforcement staff available for the airport, should have the authority to enforce the ground vehicles plan.

Part 139.331 Obstructions

Part 139 does not impose additional obstruction requirements over those in FAR Part 77 surfaces.

Part 139.333 Protection Of Navaids

Part 139 requires the holder of a Part 139 certificate to prevent construction of facilities on an airport that would degrade the operation of navaids; to protect or assist in protecting navaids from vandalism; and as much as possible, to prevent interference of navaid signals. An 8 foot high fence with 1 foot barbed wire is required around the facility and navaids. The fence must be sited to avoid FAR Part 77 imaginary surfaces.

Part 139.335 Public Protection and 14 CFR 107

Part 139 requires that certificated airports provide measures to prevent inadvertent entry to movement areas by unauthorized persons or vehicles, to protect persons and property from aircraft propeller wash, and to comply with 14 CFR 107, "Airport Security." Part 107 requires certified airports to prepare and comply with a security program. Per Part 107.4, the security program for airports (vertiports) certificated under Part 139 that serve operators with aircraft of more than 30 seats but less than 61 seats must include:

- a description of law enforcement support necessary to comply with Part 107.15(b),

- a description of the training program for those law enforcement officers to comply with Part 107.17, and

- a description of the system used to maintain records required by Part 107.23.

Passenger screening is not required at airports (vertiports) certificated under Part 139 unless departing passengers are deplaned in a sterile area at the first stop after departure. Paragraph Part 107.14 would not require an access control system unless aircraft of more than 60 seats were used, which would not apply to operations by the CTR-22C since it has a maximum capacity of 39 passengers.

A certificated vertiport must have law enforcement officers that are available and committed to respond to an incident at the airport. Law enforcement officers used to comply with Part 107 requirements must:

- have the authority to make arrests without warrant for any crime committed in the officer's presence, or for a felony if the officer has reason to suspect a person committed the felony,

- be readily identifiable by uniform and badge,

- be armed and have authority to use a firearm, and

- have completed the required training program.

It would be beneficial to have law enforcement officers present on vertiport property for a suitable time prior to air carrier operations, during air carrier operations, and for a suitable time after air carrier operations. However, a number of certificated airports do not have law enforcement officers at the airport during air carrier operations. Rather, county/local officers are called to an incident at the airport in much the same manner as to any other incident. There are no guidelines for response time for law enforcement officers to respond to an incident at an airport, but such response should generally be achieved within 5 to 10 minutes.

Part 139.337 Wildlife Hazard Management

Wildlife have been known to enter airport movement areas, even in urban areas, and can potentially damage aircraft. Part 139 requires that an ecological study be prepared. An ecological study or wildlife management plan is typically prepared by consultants qualified in this specialty area. The ecological study must contain at least:

- an analysis of events, or potential events, that prompted the study,
- identification of species and number of species,
- identification of features on or near the airport that attract wildlife, and
- description of wildlife hazards to aircraft.

The ecological study can be accomplished by vertiport management with coordination and meetings with the U.S. Department of Interior Fish & Wildlife Service, as well as appropriate state agencies.

The ecological study is submitted to the FAA for review and approval. The FAA would then determine if a wildlife management plan would be required. A wildlife management plan, if required, must contain:

- measures to alleviate the wildlife hazard;
- priorities established to modify habitat to alleviate the wildlife hazard;
- requirements for local, state, and Federal permits;
- resources of the certificate holder that will be used to implement the wildlife management plan;
- procedures for periodic evaluation and review of the plan; and
- a training program.

Part 139.339 Airport (Vertiport) Condition Reporting

Part 139, through FAA AC 150/5200-28, requires airport (vertiport) operators to use the Notices to Airmen (NOTAM) system and other measures, as required, to advise air carriers of the condition of the airport. The nine airport (vertiport) conditions to be reported include: construction on movement areas; surface irregularities on movement areas; snow, slush, or water on movement areas or ramps; snow piled or drifted contrary to Part 139.313; objects on the movement area contrary to Part 139.309; malfunction of lighting systems required by Part 139.311; unresolved wildlife hazards identified in Part 139.337; non-availability of rescue and firefighting capability required by Part 139.317 and Part 139.319; and malfunction of lighting or navigational aids.

Part 139.341 Identifying, Marking, And Reporting Construction And Other Unserviceable Areas

Part 139 requires that each operator of a certificated airport (vertiport) mark or light each construction area and unserviceable area next to a movement area, each item of construction equipment which may affect the safe movement of aircraft on the movement area, and any area adjacent to a navaid that, if traversed, could cause degradation of the signal of that navaid. It also requires operators to provide for the review of all utility plans prior to construction for compatibility with existing utilities, pipes, conduits, etc. Such identification, marking, and reporting during construction is prescribed in FAA AC 150/5370-2C, "Operational Safety On Airports During Construction," and for other times is prescribed in FAA AC 150/5200-28.

Part139.343 Noncomplying Conditions

Whenever requirements of Part 139 Subpart D cannot be met, the operator of a certificated airport (vertiport) must limit air carrier activity to those areas that are not rendered unsafe by noncompliance with Part 139 Subpart D. Noncompliance with certain Part 139 Subpart D requirements such as ARFF may require the airport to be closed to air carrier operations until Subpart D conditions are met.

APPENDIX C. MODEL VERTIPORT ZONING ORDINANCE

1.1 INTRODUCTION

The following model zoning ordinance assumes that a "vertiport zone" (VZ) would be established in the vicinity of the vertiport and included in an existing municipal zoning ordinance. A zoning ordinance for a particular municipality may be in another form.

1.2 MODEL ZONING ORDINANCE

This section of the Ordinance shall be known and may be cited as the Vertiport Zoning Ordinance.

1.2.1 Definitions - For the purposes of this Vertiport Zoning Ordinance, the following terms, phrases, words, and derivations shall have the meaning given herein.

APPROACH AND TRANSITIONAL ZONES: These zones are established to protect the vertiport from incursion by structures that would interfere with the operation of the vertiport.

APPROACH SURFACE: A surface longitudinally centered on the FATO and approach/takeoff path, extending outward and upward from the end of the primary surface and at the same slope as the approach zone height limitation slope set forth in section 1.2.5 of this Vertiport Zoning Ordinance. In plan view, the perimeter of the approach surface coincides with the perimeter of the approach zone.

APPROACH/TAKEOFF PATH: The flight track vertical flight aircraft follow when landing or taking off from a vertiport.

FATO: Final approach and takeoff area, a defined area over which the final phase of the approach to a hover or landing is completed and from which the takeoff maneuver is commenced.

HAZARD TO AIR NAVIGATION: An obstruction determined to have a substantial adverse effect on the safe and efficient utilization of the navigable airspace.

HEIGHT: For the purpose of determining the height limits in all zones set forth in this Vertiport Zoning Ordinance and shown on the Vertiport Imaginary Surfaces Plan which is Sheet __ Of __ of the Vertiport Master Plans dated __________, 19__, as amended, the datum shall be mean sea level elevation unless otherwise specified.

NONPRECISION INSTRUMENT RUNWAY: A runway having an existing instrument approach procedure utilizing air navigation facilities with only horizontal guidance, or area type navigation equipment, for which a straight-in nonprecision instrument approach procedure has been approved or planned.

OBSTRUCTION: Any structure, growth, or other object, including a mobile object, which exceeds a limiting height set forth in section 1.2.5 of this Vertiport Zoning Ordinance.

PERSON: An individual, firm, partnership, corporation, company, association, joint stock association, or government entity; includes a trustee, a receiver, an assignee, or a similar representative of any of them.

PRECISION INSTRUMENT FATO: A FATO having an existing precision instrument approach procedure utilizing an instrument landing capabilities employing a microwave landing system (MLS) or differential global positioning system (dGPS). It also means a FATO for which a precision approach system is planned and is so indicated on an approved vertiport layout plan or any other planning document.

PRIMARY SURFACE: The horizontal plane having the size and shape of the FATO. It is at the highest elevation of the highest point on the TLOF(s). It abuts the inner edge of the approach surface, and for IFR, may extend beyond the FATO. The FATO is the same as the designated takeoff and landing area referenced in FAR Part 77.29(a).

STRUCTURE: An object, including a mobile object, constructed or installed by man, including but not limited to: buildings, towers, cranes, smokestacks, earth formation, and overhead transmission lines.

TLOF: Touchdown and liftoff area. A load-bearing, generally paved area, normally centered in the FATO, on which the vertical flight aircraft lands or takes off.

TRANSITIONAL SURFACES: FAR Part 77, Subpart C surfaces which extend outward from the lateral boundaries of the primary and approach surfaces to prevent construction or placement of objects that may interfere with the facility operation.

TREE: Any object of natural growth.

VERTIPORT: The vertiport name in the ordinance.

VERTIPORT ELEVATION: Feet above mean sea level of the highest point of the TLOF(s). This elevation may be revised from time to time due to vertiport improvement projects.

VISUAL RUNWAY: A runway intended solely for the operation of aircraft using visual approach procedures under visual meteorological conditions.

1.2.2 <u>Vertiport Zones</u>

1.2.2.1 <u>Purpose</u> - A vertiport zone is intended to prevent the creation or establishment of hazards to air navigation; to eliminate, remove, or mitigate hazards to air navigation; to

mark or light obstructions to air navigation to and from the __(name)__ Vertiport (hereafter called "The Vertiport").

1.2.2.2 Permitted Uses - The following uses[1] are permitted in the VZ in accordance with the standards of Article ___ of this Ordinance. Uses listed as permitted in the Residential District, Commercial District, Industrial District, Rural Development District, and Resource Protection District except for those uses for which the effects are described in section 1.2.7 of this Ordinance. In addition, no residential structures, churches, hotels and motels, and other lodging and noise sensitive uses can be located within the 65 L_{dn} aircraft noise contour as shown on Sheet __ of __ of the _(name)_ Vertiport Master Plans, dated _________ , 19__, as amended.

1.2.2.3 Conditional Use - Those uses, permitted as *conditional* uses[2], that are allowed in the Residential District, Commercial District, Industrial District, Rural Development District, and Resource Protection District in accordance with the standards of Article ___ of this Ordinance, and upon review and approval of the Planning Board in accordance with the provisions of Article __ of the Ordinance, are permitted in the VZ, except those for which the effects are described in section 1.2.7 of this Ordinance. In addition, no noise sensitive uses as described in section 1.2.2.2 of the Ordinance can obtain a *conditional use permit* to be located within the 65 L_{dn} noise contour as shown on Sheet __ of __ of the _(name)_ Vertiport Master Plans, dated _________ , 19__, as amended.

1.2.3 Standards Within Vertiport Zones - It is hereby found that an obstruction has the potential for endangering the lives and property of uses of The Vertiport property and/or occupants of the land in its vicinity; that an obstruction may affect existing and future instrument approach minimums of the Vertiport; and that an obstruction may reduce the size of the areas available for the landing, takeoff, and maneuvering of aircraft, thus tending to destroy or impair the utility of the Vertiport and the public investment therein. Accordingly, it is declared:

1. that the creation or establishment of an obstruction has the potential of being a public nuisance and may injure the region served by the Vertiport;

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[1] The intent of this paragraph is to list other zoning districts described in the zoning ordinance in which permitted uses would be allowed within the VZ. This paragraph also notes the exceptions to permitted uses such as noise sensitive areas, and refers to a set of vertiport plans which typically includes a land use plan and an imaginary surfaces plan.

[2] The intent of this paragraph is to list other zoning districts described in the zoning ordinance in which permitted uses would be conditionally allowed within the VZ. This paragraph also notes the exceptions to permitted uses such as noise sensitive areas, and refers to a set of vertiport plans which typically includes a land use plan and an imaginary surfaces plan.

2. that it is necessary in the interest of public health, public safety, and general welfare of the community that the creation or establishment of obstructions that are a hazard to air navigation be prevented; and

3. that the prevention of these obstructions should be accomplished, to the extend legally possible, by the exercise of the police power without compensation.

It is further declared that the prevention of the creation or establishment of hazards to air navigation, the elimination, removal, alteration, or mitigation of hazards to air navigation, or marking and lighting of obstructions, are public purposes for which a political subdivision may raise and expend public funds and acquire land or interest in land.

1.2.4 <u>Description of Vertiport Zones</u> - In order to carry out the provisions of this Vertiport Zoning Ordinance, there are hereby created and established certain zones which include all of the land lying beneath the approach surfaces and transitional surfaces as they apply to the Vertiport. Such zones are shown on the Vertiport Imaginary Surfaces Plan which is Sheet __ Of __ of the Vertiport Master Plans dated ________, 19__, as amended, which is attached to this Ordinance and made a part hereof. The various zones are hereby established and defined for the most part, relative to the ends of runways 4, 22, 17 and 35 at the Vertiport as follows:[3]

1.2.4.1 <u>Primary Surface</u>

FATO 4: The primary surface (visual approach) is a horizontal plane having the same size and shape as the FATO; a width of 250 feet and a length of 250 feet.

FATO 22: The primary surface (nonprecision approach) is a horizontal plane having the same size and shape as the FATO; a width of 300 feet and a length of 300 feet.

FATO 17: The primary surface (6-degree precision instrument approach) is a horizontal plane having the same size and shape as the FATO; a width of 300 feet and a length of 1,225 feet.

FATO 35: The primary surface (9-degree precision instrument approach) is a horizontal plane having the same size and shape as the FATO; a width of 250 feet and a length of 550 feet.

1.2.4.2 <u>Approach Surface</u>

[3]For illustrative purposes, an approach surface applicable to a visual approach FATO, a nonprecision instrument approach FATO, a FATO with a 6-degree precision instrument approach, and a FATO with a 9-degree precision instrument approach is assumed. The FATOs, named in reference to magnetic north for purposes of this study, are named 4, 22, 17, and 35, respectively.

FATO 4: Visual Approach - The inner edge of this approach zone coincides with the width of the primary surface and is 250 feet wide. Its centerline is the continuation of the centerline of the FATO. The approach zone expands upward and outward uniformly to a width of 650 feet at a horizontal distance of 4,000 feet from the primary surface. The slope of the approach surface is 20:1 (horizontal:vertical).

FATO 22: Nonprecision Instrument Approach - The inner edge of this approach zone abuts the edge of the primary surface and is 500 feet wide. Its centerline is the continuation of the centerline of the FATO. The approach zone extends outward and upward for a horizontal distance of 5,000 feet where its width is 2,000 feet. The slope of the approach surface is 20:1 (horizontal:vertical).

FATO 17: 6-Degree Precision Instrument Approach - The inner edge of this approach zone coincides with the width of the primary surface and is 300 feet wide. Its centerline is the continuation of the centerline of the FATO. The approach zone begins 1,225 feet from the end of the FATO and extends outward for 25,000 feet along the final approach course. It flares from a beginning width of 1,000 feet to an ending width of 6,000 feet. The slope of the approach surface is 17:1 for a horizontal distance of 5,000 feet where its width is 2,000 feet. Thereafter, the slope of the approach surface is 20:1 (horizontal:vertical).

FATO 36: 9-Degree Precision Instrument Approach - The inner edge of this approach zone coincides with the width of the primary surface and is 250 feet wide. The approach zone expands upward and outward uniformly to a width of 3,000 feet at a horizontal distance of 10,000 feet from the primary surface. Its centerline is the continuation of the centerline of the FATO. The slope of the approach surface is 10:1 (horizontal:vertical).

1.2.4.3 Transitional Surface:

FATO 4: The transitional surfaces extend upward and outward from the lateral boundaries of the primary surface and the approach surfaces at a slope of 2:1 for a distance of 325 feet measured horizontally from the centerline of the primary and approach surfaces.

FATO 22: The transitional surfaces extend upward and outward from the lateral boundaries of the primary surface at a slope of 4:1 for a distance of 350 feet measured horizontally from the centerline of the primary surface. The distance varies along the boundaries of the approach surface from 350 feet at the primary surface end to 0 feet at a distance of 2,000 feet from the primary surface.

FATO 17: The transitional surface extends outward at right angles from the edge of the approach surface at a slope of 7:1 (horizontal to vertical). At the point closest to the edge of the primary surface (also known as the IFR FATO), the transitional surface is 600 feet wide on either side of the approach surface. The width of the transitional surface uniformly widens to 1,500 feet at the end of, and on either side of the approach surface, at a point 25,000 feet from the edge of the primary surface. The point is also the end of the precision instrument approach surface.

FATO 35: The transitional surfaces adjacent to the primary surface slope outward and upward at a ratio of 3:1 for a horizontal width of 6,000 feet. The transitional surfaces also rise from the edges of the precision approach trapezoid at a ratio of 7:1. These planes have a horizontal width of 600 feet at the beginning of the approach trapezoid and flare to a horizontal width of 960 feet at the outer end of the approach surface (horizontal:vertical).

1.2.5 Vertiport Zone Height Limitations - Except as otherwise provided in this Vertiport Zoning Ordinance, no structure shall be erected, altered, or maintained, and no tree shall be allowed to grow in any zone created by this Vertiport Zoning Ordinance to a height in excess of the applicable height herein established for such zone. Such applicable height limitations are hereby established for each of the zones in question as follows:

FATO 4: For the visual approach surface, the vertiport zone height limit slopes 8 feet outward for each foot upward (8:1) beginning at the end of and at the same elevation as the primary surface (____ MSL) and extending to a horizontal distance of 4,000 feet along the extended FATO centerline.

FATO 22: For the nonprecision approach surface, the vertiport zone height limit slopes 20:1 beginning at the end of and at the same elevation as the primary surface (____ MSL) and extending to a horizontal distance of 5,000 feet along the extended FATO centerline.

FATO 17: For the 6-degree precision approach surface, the vertiport zone height limit slopes 17:1 beginning at the end of and at the same elevation as the primary surface (____ MSL) and extending to a horizontal distance of 25,000 feet along the extended FATO centerline.

FATO 35: For the 9-degree precision approach surface, the vertiport zone height limit slopes 10 feet outward for each foot upward beginning at the end of and at the same elevation as the primary surface (____ MSL) and extending to a horizontal distance of 10,000 feet along the extended FATO centerline.

1.2.6 Use Restrictions - Notwithstanding any other provisions of this Ordinance, no use may be made of land or water within any zone established by this Vertiport Zoning Ordinance in such a manner as to create electrical interference with navigational signals or radio communication between the vertiport and aircraft, make it difficult for pilots to distinguish between vertiport lights and other lights, result in glare in the eyes of pilots using the vertiport, impair visibility in the vicinity of the vertiport, create bird strike hazards, or otherwise in any way endanger or interfere with the landing, takeoff, or maneuvering of aircraft intending to use the Vertiport.

1.2.7 Nonconforming Uses - The purpose of this section is to identify a course of action for land use that is not in conformance with this ordinance. Such nonconforming land uses may exist at the time that this ordinance is adopted, and said land use will have to come into conformance with this ordinance at such time as either the use or the ownership of the property changes.

1.2.7.1 Nonconformance Provisions

Nonconformance provisions in ARTICLE ___, Section ________ of the Ordinance shall apply to this Vertiport Zoning Ordinance. Such provisions describe the process by which nonconforming land uses are allowed to continue, and at which point they must be discontinued and brought into conformance with this ordinance.

1.2.7.2 Marking and Lighting - Notwithstanding the preceding provision of this section, the owner of any existing nonconforming structure or tree is hereby required to permit the installation, operation, and maintenance thereon of such markers and lights as shall be deemed necessary by the _______________ (*Insert The Name Of Operators Of The Vertiport*) to indicate to the operators of aircraft in the vicinity of the vertiport the presence of such vertiport obstruction. Such markers and lights shall be installed, operated, and maintained at the expense of ___________ (*Insert The Name Of Operators Of The Vertiport*).

1.2.8 Permits

1.2.8.1 Future Uses - Except as specifically provided hereunder, no material change shall be made in the use of land, no structure shall be erected or otherwise established, and no tree shall be planted in any zone hereby created unless a permit therefor shall have been applied for and granted. Each application for a permit shall indicate the purpose for which the permit is desired, with sufficient particularity to permit it to be determined whether the resulting use, structure, or tree would conform to the regulations herein prescribed. If such determination is in the affirmative, the permit shall be granted. No permit for a use inconsistent with the provisions of this Vertiport Zoning Ordinance shall be granted unless a variance has been approved in accordance with section 1.2.8.4.

In areas lying within the limits of the approach zones but at a horizontal distance of not less than 4,200 feet from each end of the FATO, no permit shall be required for any tree or structure less than 75 feet.

1.2.8.2 Existing Uses - No permit shall be granted that would allow the establishment or creation of an obstruction or permit a nonconforming use, structure, or tree to become a greater hazard to air navigation than it was on the effective date of this Vertiport Zoning Ordinance or any amendments thereto or than it is when the application for a permit is made. Except as indicated, all applications for such a permit shall be granted.

1.2.8.3 Nonconforming Uses Abandoned or Destroyed - Whenever the Board Of Selectmen (*zoning authority*) determines that a nonconforming tree or structure has been abandoned or more than 80 percent torn down, physically deteriorated, or decayed, no permit shall be granted that would allow such structure or tree to exceed the applicable height or otherwise deviate from the zoning regulations.

1.2.8.4 Variances - Any person desiring to erect or increase the height of any structure, or permit the growth of any tree, or use property, not in accordance with the regulations prescribed in this Vertiport Zoning Ordinance, may apply to the ____________ (*Insert The Name Of The Board of Appeals*) for a variance from such regulations pursuant to requirements described in ARTICLE ___, Section _____ of the Ordinance. The application for variance shall be accompanied by a determination from the Federal Aviation Administration as to the effect of the proposal on the operation of air navigation facilities and the safe, efficient use of navigable airspace. Such variances shall be allowed where requirements of Section __________ and Section ________ of ARTICLE __ of the Ordinance are met and will not create a hazard to air navigation, will do substantial justice, and will be in accordance with the spirit of this Vertiport Zoning Ordinance. Additionally, no application for variance to the requirements of this Ordinance may be considered by the Board of Appeals unless a copy of the application has been furnished to the Vertiport Manager for advice as to the aeronautical effects of the variance. If the Vertiport Manager does not respond to the application within ___ (*Insert Municipal Requirement*) days after receipt, the Board of Appeals may act on its own to grant or deny said application for variance.

1.2.8.5 Obstruction Marking and Lighting - Any permit or variance granted may, if such action is deemed advisable to effectuate the purpose of this Vertiport Zoning Ordinance and be reasonable in the circumstances, be so conditioned as to require the owner of the structure or tree in question to install, operate, and maintain, at the owner's expense, such markings and lights as may be necessary. If deemed proper by the concurrence of the Board of Appeals and the __________ (*Insert Operators Of The Vertiport*), this condition may be modified to require the owner to permit _________ (*Insert Operators Of The Vertiport*), at its own expense, to install, operate, and maintain the necessary markings and lights.

1.2.9 Conflicting Regulations - Where there exists a conflict between any of the regulations or limitations prescribed in this Vertiport Zoning Ordinance and any other regulations applicable to the same area, whether the conflict be with respect to the height of structures or trees, and the use of land, or any other matter, the more stringent limitation or requirement shall govern and prevail.

1.2.10 Severability - If any of the provisions of this Vertiport Zoning Ordinance or the application thereof to any person or circumstances are held invalid, such invalidity shall not affect other provisions or applications of the Vertiport Zoning Ordinance that can be given effect without the invalid provision or application, and to this end, the provisions of this Vertiport Zoning Ordinance are declared to be severable.

1.2.11 Effective Date - WHEREAS, the immediate operation of the provisions of this Vertiport Zoning Ordinance is necessary for the preservation of the public health, public safety, and general welfare, this Vertiport Zoning Ordinance shall be in full force and effect from and after its passage by the _____________ (Municipality) and publication and posting as required by law. Adopted by the _________ (Municipality) this ____ day of ___________, 19__.